PROCEEDINGS OF THE 11TH TAWIRI SCIENTIFIC CONFERENCE

" People, Livestock and Climate change: challenges for sustainable biodiversity Conservation"

6th - 8th December 2017
Arusha International Conference Centre,
Arusha Tanzania

TANZANIA WILDLIFE RESEARCH INSTITUTE
(TAWIRI)

PROCEEDINGS OF THE
ELEVENTH TAWIRI SCIENTIFIC CONFERENCE,
6TH – 8TH DECEMBER 2017,
ARUSHA INTERNATIONAL CONFERENCE CENTRE,
TANZANIA

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CONFERENCE THEME

"People, Livestock and Climate change: Challenges for Sustainable Biodiversity Conservation"

MESSAGE FROM THE ORGANIZING COMMITTEE

The Tanzania Wildlife Research Institute (TAWIRI) scientific conferences are biennial events. This year's gathering marks the 11th scientific conference under the theme: ***"People, Livestock and Climate change: Challenges for sustainable biodiversity conservation"***. The theme primarily aims at contributing to global efforts towards sustainable wildlife conservation. The platform brings together a wide range of scientists, policy markers, conservationists, NGOs representatives and civil society representatives from various parts of the world to present their research findings so that the management of wildlife resources and natural resources can be based on sound scientific information in Tanzania and Africa at large. During the conference, there will be oral and poster scientific presentations as well as a number of organized symposia that aim at addressing the main conference theme and sub-themes. It is our hope that the conference presentations will address current wildlife management challenges and propose solutions and mitigations especially issues of population growth that is coupled with increased demand of land for cultivation, settlement and grazing; influx of livestock in protected areas as well as the impacts of climate change. Moreover, recommendations generated from this conference are expected not only to improve and safeguard wildlife resources in the current era of increasing challenges for biodiversity conservation, but also devise a way on how better communities can rationally and sustainably utilize ecosystems services.

On behalf of the TAWIRI Board, Management and staff of TAWIRI, the 0rganizing committee of the 11th TAWIRI Scientific Conference is honoured and pleased to invite all scientists, conservationists, management authorities, government officials and representatives of NGOs and civil societies organizations to this important conference, KARIBUNI SANA.

Organizing Commettee Members

Angela Mwakatobe	Chairperson
Janemary Ntalwila	Secretary
Victor Kakengi	Member
Alex Lobora	Member
Mwita Machoke	Member
Daniel Wanna	Member
Ritha Billy	Member
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Flora Kipuyo	Member

SPEECH OF THE DIRECTOR GENERAL, DR. SIMON MDUMA, AT THE OFFICIAL OPENING OF THE 11TH TAWIRI SCIENTIFIC CONFERENCE AT ARUSHA INTERNATIONAL CONFERENCE CENTER DECEMBER 6TH , 2017

Honourable Minister, Dr. Hamis Kigwangalla (MP), Minister for Natural Resources and Tourism,
Hon. Mrisho Gambo, Regional Commissioner – Arusha,
Honourable Chairperson of the TAWIRI Board, Professor Apollinaria Pereka,
Honourable Members of the TAWIRI Board,
TAWIRI Management Team,
Distinguished Guests,
Conference Participants,
Ladies and Gentlemen.

Good morning!

First and foremost, allow me Honourable Minister to take this opportunity to thank you in person, for dedicating part of your time for this important event, despite your very tight schedule. I would also like to thank Professor Pereka and Members of the TAWIRI Board for agreeing to be with us today on this very special occasion.
Also, many special thanks to all conference participants who have gathered here with us today. We appreciate the immense sacrifice you have made in terms of time and resources. On behalf of the TAWIRI Management Team, I wish to take this opportunity to express our very sincere gratitude for your attendance to this conference.

For those who have come from outside Arusha Municipality, I take this opportunity to welcome you to Arusha.

Honourable Minister,

On behalf of the Institute's Management, allow me to express our very sincere thanks to organizations that made this conference possible namely the Tanzania National Parks (TANAPA), Ngorongoro Conservation Area Authority (NCAA), Tanzania Wildlife Authority (TAWA), Ortello Business Company (OBC), Grumeti Fund, GIZ, Oikos, Wildlife Conservation Society (WCS), The Nature Conservancy (TNC), Norwegian Institute for Nature Research (NINA), Frankfurt Zoological Society (FZS), Jane Goodall Institute (JGI), Ugalla Primates Research Project and the Arusha International Conference Centre (AICC). These organizations are not only our recurrent supporters to these particular events but also support a wide array of conservation actictivities in various parts of the country. We sincerely thank you all and please keep up the spirit!

Honourable Minister,

My task this morning is very simple, and I wouldn't like to misuse the privilege that has been entrusted to me. My duty is to welcome the Chairperson of the TAWIRI Board of Directors, Professor Pereka to say a few words and to subsequently welcome you to address this congregation and officially open the 11th TAWIRI Scientific Conference.

With these few remarks, **Honourable Minister,** I would now like to welcome Professor Pereka, the Chairperson of the TAWIRI Board of Directors.

Professor Pereka please welcome!!

SPEECH OF THE CHAIRPERSON, PROF. APOLLINARIA E. PEREKA, AT THE OFFICIAL OPENING OF THE 11TH TAWIRI SCIENTIFIC CONFERENCE AT ARUSHA INTERNATIONAL CONFERENCE CENTER DECEMBER 6TH , 2017

Honourable Dr.Hamis Kigwangalla (MP), Minister for Natural Resources and Tourism,
Hon Mrisho Gambo, Regional Commissioner – Arusha,
Members of the TAWIRI Board,
Director General, Dr Simon Mduma and the Management of TAWIRI,
Conference Participants,
Distinguished Guests,
Ladies and Gentlemen.

First and foremost, I would like to thank the Almighty God for making it possible for me to witness and attend the 11th TAWIRI Scientific Conference.

Secondly, let me take this opportunity to thank you, Hon. Dr. Hamis Kigwangalla (MP), the Minister of Natural Resources and Tourism, for agreeing to officiate the opening of the Eleventh TAWIRI Scientific Conference. I would like to express my most sincere appreciation to you, Hon. Minister a nd the Ministry as a whole for moral and material support to the Institute.

Honourable Minister,

This conference has brought together about 300 participants including long-term wildlife research scientists from within and outside Tanzania. Let me reiterate the Director General's remarks in recognising all participants for their attendance to this conference.

Honourable Minister,

It is worth noting that the management of our protected areas in Tanzania is the responsibility of your Ministry through the Wildlife Division (WD), Tanzania Wildlife Authority (TAWA), Tanzania National Parks (TANAPA), Ngorongoro Conservation Area Authority (NCAA), Forestry and Beekeeping Division (FBD) and Tanzania Forestry Services (TFS). However, for these management authorities to achieve sound management of our natural resources, appropriate scientific information is paramount. Given this fact, there is a need for more support to TAWIRI to ensure generation of scientific information to direct our conservation actions. I acknowledge the attendance of management authorities at this conference.

Honourable Minister,

TAWIRI Scientific Conferences are Biennial events that aim at bringing together prominent and up-coming wildlife scientists and conservationists from across the world to exchange information and experience on wildlife research and conservation. Initiation and continuation of these conferences give evidence of high regard that TAWIRI takes in fulfilling its mandate. Therefore, research findings presented by wildlife scientists in this gathering is one of the ways by which TAWIRI avails scientific information to stakeholders charged with the responsibility for conserving our wildlife resources.

Honourable Minister,

For those who attended the previous TAWIRI Conferences, will recall that conference themes have been changing from one conference to the other to reflect prevailing situations and needs for wildlife conservation. This year's theme is **"*People, Livestock and Climate change: Challenges for sustainable biodiversity conservation*".** This theme was selected in recognition of the current challenges facing wildlife conservation in the country. Results of an aerial Census of wildlife, livestock and bomas which was conducted in the Serengeti ecosystem in September 2016 clearly indicated that in the eastern part of the Serengeti there is an increasing trend of livestock that interacts with wildlife within the protected areas (NCA and Loliondo GCA). Severe overgrazing can convert large tracts of pasture into bare land, leading to bush encroachment and spreading of invasive plants, thus reducing the overall grazing carrying capacity of an ecosystem. Also, increasing livestock affects the livelihoods of pastoral communities as the herds exceed carrying capacity of the land and the livestock become more susceptible to climate shifts and drought.

Honourable Minister,

I believe that scientific information has been the backbone of the country's success story in wildlife conservation. Thus, more scientific information is needed on how to improve the livelihood of communities around protected areas by enhancing economic growth, conserving our natural resources and mitigating climate change impacts for sustainable conservation of biodiversity.

In this conference, we will have four key note papers, three symposia and seven parallel sessions with a total of 167 oral and 19 poster presentations that will be presented and discussed. Full manuscripts will be submitted to TAWIRI for review process and those that qualify will be published in the 11th TAWIRI scientific conference proceedings. I believe that, if used properly, these findings will contribute significantly to the sustainable wildlife conservation in the country and the region at large.

Honourable Minister,

TAWIRI is mandated to carry out, coordinate and supervise wildlife research in the United Republic of Tanzania. For TAWIRI to fulfil 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 achieve its goal. We are grateful to the Tanzania Wildlife Authority, Tanzania National Parks, Ngorongoro Conservation Area Authority, Tanzania Forest Services, National Research Foundation of Korea, European Union (EU), the World Bank, Grumeti Fund, Norwegian University of Science and Technology, Japan Society for Promotion of Science (JSPS), Frankfurt Zoological Society (FZS), Wildlife Conservation Society (WCS) and the United States Agency for International Development (USAID) 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.

Honourable Minister,

TAWIRI is working in close collaboration with other researchers from within and outside the country in generating information important for conservation of wildlife resources. This is witnessed through the number of projects that were registered by the Institute during the financial year 2016/2017, where a total of 157 projects and 523 research scientists were registered and supervised. I am pleased to inform you that the number of Tanzanian research scientists has almost doubled over the past four years from 125 scientists in the financial years 2012/2013 to 212 scientists in 2016/17.

Furthermore, as a strategy for enhancing the capacity of carrying out wildlife research, the Institute has established donor-funded collaborations with local and international institutions including the following projects:

- Serengeti Wild-dog Project (Funded by TANAPA, NCAA, Grumeti Fund, Bio-Top Tz Ltd and Institute of Science and Technology Norway) – Dr. Ernest Eblate.
- Rabies control project around Serengeti ecosystem (Funded by Biotechnology and Biological Sciences Research Council through University of Glasgow UK) – Dr. Julius Keyyu.
- Management of human-carnivore conflict and community adaption to climate change, funded by UNDP – Dr. Wilfred Marealle.
- Parasites, bacteria and viral pathogens of wildlife in Tanzania (Funded by National Research Foundation of Korea through Korea National Research Resource Centre),– Dr. Julius Keyyu.
- Wildlife studies in Tanzania; Africa-Japan-Core to core Programme (Funded by Japan Society for Promotion of Science) – Dr. Edward Kohi.
- Linking biodiversity, ecosystem functions and services in the Greater Serengeti-Mara ecosystem (GSME)-drivers of change, causalities and sustainable management strategies (Funded by the European Union) – Dr. Robert Fyumagwa.
- Tarangire-Manyara wildlife corridor vegetation classification and mapping project (Vollmar Natural Lands Research Group) – Dr. Victor Kakengi.
- Endangered Ecosystems of Northern Tanzania (Funded by Conservation Society (WCS-USA) – Dr. Alex Lobora.
- Animal census (Funded by TANAPA, TAWA, NCAA, FZS and WCS) – Dr. Simon Mduma.
- Ecology and Behavioral Studies of Elephant in the Selous-Mikumi Ecosystem (Funded by WWF and FZS) – Dr. Edward Kohi.
- Investigation of Traditional Use of Medicinal Plants in Northern Tanzania' (Funded by Korea National Research Foundation (KNRF) – Dr. Bukombe John.
- The Birds of Western Tanzania: A Pictorial Guide Book for Muyovosi-Malagarasi Ramsar

Site, Minziro Forest Reserve, Gombe, Mahale, Rubondo and Saanane National Parks (Funded by Korea National Research Foundation (KNRF) through National Institute of Biological Resources (NIBR)) – Dr. Edward Kohi.

- REGROW (Funded by World Bank through MNRT) – Coordinator - Dr. Alex Lobora.
- Ecology of black rhinocerous in Selous Ecosystem (WCS) – Dr. Edward Kohi.

Honourable Minister,

Despite the aforementioned achievements, the Institute requires more support for it to fulfilling her mandate given the vast amount of work ahead of us. These include the need for a state of the art molecular laboratory to avoid huge cost for exporting samples abroad, office space for researchers, expansion of research centres and stations in all strategic zones, inadequate staff in terms of number and skills, and working gears such as vehicles just to mention a few. At present, the institute depends on support from foreign donors leading to difficulties in implementing domestic research priorities. In this regard, I would like to urge your Ministry to consider ways of helping the Institute to address the aforementioned challenges.

Honourable Minister,

Organizing TAWIRI Scientific Conference requires significant resources. Many donors and collaborating Institutions have been supporting and sponsoring TAWIRI Scientific Conferences. I humbly request you Honourable Minister to offer certificates of appreciation to our outstanding conference sponsors.

This year's conference is sponsored by your Ministry of Natural Resource and Tourism (MNRT), Tanzania National Parks (TANAPA), Ngorongoro Conservation Area Authority (NCAA), Tanzania Wildlife Authority (TAWA), Orttello Business Corporation LTD (OBC), Grumeti Fund, GIZ, Oikos, Wildlife Conservation Society (WCS), The Nature Conservancy (TNC), Norwegian Institute for Nature Research (NINA), Frankfurt Zoological Society (FZS), and Tanzania Association of Tour Operators (TATO). We thank them all for their support and we hope they will continue to support not only these conferences but also conservation activities across the country.

Honourable Minister

Organizing such a big conference is not a simple work, therefore, allow me Honourable Minister to thank the Management of TAWIRI and the Conference Organizing Committee for the efforts they have put to organizing this year's conference. Hongereni sana!

Honourable Minister,
With these few remarks, I now have the great honour to welcome you, Honorable Minister, to address this congregation and officially open the Eleventh TAWIRI Scientific Conference.

THANK YOU

SPEECH OF DEPUTY MINISTER, MINISTRY OF NATURAL RESOURCES AND TOURISM, HONARABLE JAPHET HASUNGA (MP) AT THE OFFICIAL OPENING OF THE 11TH TAWIRI SCIENTIFIC CONFERENCE AT ARUSHA INTERNATIONAL CONFERENCE CENTER DECEMBER 6TH , 2017

Hon. Mrisho Gambo, Regional Commissioner – Arusha,
Chairperson of the TAWIRI Board, Professor Apollinaria Pereka,
Members of the TAWIRI Board,
Director General, Dr. Simon Mduma,
Management of TAWIRI,
Conference Participants,
Distinguished Guests,
Ladies and Gentlemen,

First and foremost, allow me, Chairperson, to extend my sincere gratitude to you, and the Management of TAWIRI for inviting me to officiate the opening of the eleventh TAWIRI scientific conference here in Arusha for the first time.I feel greatly honoured.

Chairperson, Conference Participants,
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 from abroad to come to this meeting. Your presence is highly appreciated and signifies your positive 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".

Chairperson, Conference Participants,

TAWIRI is mandated to conducting, coordinating as well as disseminating wildlife research findings to stakeholders in the country in order to guide conservation actions. These biennial conferences have therefore been useful in enabling the Institute to fulfil this important responsibility. My understanding is that one of the objectives of these conferences is to continually provide up to date information on priority research areas so as to guide development of effective conservation strategies for wildlife resources in the country. I have been informed that proceedings of the 10th TAWIRI scientific conference have been printed, distributed and posted on the TAWIRI website for the same purpose and therefore I urge management authorities to make use of these findings as often as possible.

Chairperson, Conference Participants,
The Ministry of Natural Resources and Tourism recognises the importance of TAWIRI scientific conferences as a platform for disseminating research findings carried out and continue to be carried out in various parts of the country. In this regard, the Ministry will continue to support these conferences to the best of her ability.

Chairperson, Conference Participants,

The Ministry of Natural Resources and Tourism also recognises that we have a wide range of stakeholders in the wildlife sector who are the end-users of the findings generated by researchers. Your attendance to these conferences is therefore of paramount importance. Let me take this opportunity to request wildlife managers, tour operators, conservationists and development partners, to mention a few, to continue participating in these scientific conferences to keep pace with the ongoing challenges facing conservation of natural resources in the country and work alongside with other stakeholders in mitigating these challenges.

Chairperson, Conference Participants,

The theme of this year conference is "People, Livestock and Climate change: Challenges for sustainable biodiversity conservation". This theme is indeed timely not only to Tanzania but also the entire world. More than 40% of the terrestrial globe is covered by rangelands and their inhabitants make up over one-third of the global population. The ways in which we interact with these environments impacts on us all, through their production, their biodiversity and other ecosystem services, and their fast-changing social and demographic configurations. Over the past four decades, the natural rangeland in Tanzania has been decreasing in size due to increase of human and livestock populations. For example, human population has increased from 9 million in 1961 to over 45 million in 2012, suggesting huge demand for more land for settlements, agriculture and grazing domestic stocks. To date, we have an estimated human and cattle populations of about 50 and 25 million respectively suggesting a huge course of concern if proper and scientific management plans are not put in place. Not to mention conversion of wild lands into big state farms, mining, infrastructure development and expansion of cities and towns. (Updated number of livestock caught in the Serengeti Ecosystem and cases will be sent to you).

In principle, as human populations grow, so do the resource demands imposed on ecosystems. The ever-increasing demand for land is a concern to all of us and puts preservation of natural resources in limbo. There is a danger of forgetting the fundamental principle that natural resources are not invulnerable and will be available indefinitely. In this regard, I urge wildlife scientists to continuously provide scientific information to the Government, wildlife management authorities, conservation and development partners that will help reduce anthropogenic impacts on nature as well as information that could help guide the development of effective conservation and development strategies.

Chairperson, Conference Participants,

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 earning (25% of forex earnings) contributing about 17.5% 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 present and future generations.

Chairperson, Conference Participants,

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 unreliable income, they are likely to destroy the environment in which their livelihood depends on. Improving our people's welfare while ensuring sustainable use of our natural resources is a challenge that needs to be addressed by all of us.

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.

Chairperson, Conference Participants,

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 to take on board issues of socio-economic development and climate change. I understand that most of the long-term research work has concentrated in famous protected areas in northern parts of the country and largely on some groups of animals or subjects. I, therefore, kindly request wildlife scientists to diversify their efforts to less studied but biodiverse areas such as the Selous, Ruaha-Rungwa and Katavi-Rukwa ecosystems. I understand the high cost involved in working in these areas due to lack of research facilities among others but the good news is that my Ministry has recently initiated a six-year's project REGROW worth US$150 Million aiming at promoting wildlife conservation and tourism in these areas. More specifically, some of these funds will be used for putting in place infrastructure development for research (facilities such as housing and mini labs) in the Selous Game Reserve and Ruaha National Park. My hope is that once completed, these facilities will promote research undertakings in these areas at affordable cost as it is for other areas in the north (e.g. Serengeti National Park).

Second, I call upon wildlife research scientists to consider investing in understanding impacts of socio-economic activities to wildlife conservation in the country and find scientific ways of mitigating such impacts in line with the current conference theme. For example, how can we provide for human livelihoods whilst maintaining the ecological integrity of important wildlife ecosystems at the same time? Is there a future for natural resources outside protected areas given the escalating human population? To what extent does existing wildlife policies or legislative issues help attain effective conservation of wildlife? Recent records suggest that illegal hunting for whatever reason has significantly declined over the past couple of years due to deliberate government efforts to combat poaching same. The resultant effect to this would be increasing wildlife numbers and possible conflicts resulting from crop raiding, predation and human mortalities. I urge scientists to look into scientific ways of evading wildlife conflicts before they occur.

Chairperson, Conference Participants,

My Ministry recognizes the importance of wildlife research and will, therefore, continue to support the Institute through the provision of basic and operational funding. I also understand that the Wildlife Act No.5 of 2009 has a provision for Management Authorities to provide financial support to TAWIRI and other service oriented institutions under my ministry. I'm happy to inform you that my ministry has already prepared a draft amendment that will ensure the implementation of this provision. Let me take this opportunity to also ask TAWIRI to find other mechanisms of sustainable funding research and related works to supplement the ongoing government efforts.

Chairperson, Conference Participants,

Let me also ask development agencies and partners to once again continue supporting existing research initiatives. I am grateful to note that a positive development already exists with the following donors: European Union, The World Bank, 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.

Chairperson, Conference Participants,

I'm informed that this conference has been made possible with efforts from many stakeholders. I would like to thank Tanzania National Parks (TANAPA), Ngorongoro Conservation Area Authority (NCAA), Tanzania Wildlife Authority (TAWA), Ortello Business Company (OBC), Grumeti Fund, GIZ, Oikos, Wildlife Conservation Society (WCS), The Nature Conservancy (TNC), Norwegian Institute for Nature Research (NINA), Frankfurt Zoological Society (FZS), Jane Goodall Institute (JGI), Ugalla Primates Research Project, Tanzania Tour Operators (TATO) and the Arusha International Conference Centre (AICC) for their generous support.

Chairperson, 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. I urge you to spare a few days after the conference to visit some of these fascinating tourist attractions in the country. Indeed, you will find a home away from your home. With these remarks, I now have the pleasure to declare that the Eleventh TAWIRI Scientific Conference is officially opened.

THANK YOU

CLOSING REMARKS BY THE PERMANENT SCRETARY MINISTRY FOR NATURAL RESOURCES AND TOURISM, HON. MAJOR GENERAL GAUDENCE MILANZI, AT THE ELEVENTH TAWIRI SCIENTIFIC CONFERENCE HELD AT ARUSHA INTERNATIONAL CONFERENCE CENTRE (AICC), ARUSHA, DECEMBER 6th – 8th, 2017

Hon. Mrisho Gambo, Regional Commissioner – Arusha,
Chairperson of the TAWIRI Board, Prof. Apollinaria Pereka,
TAWIRI Management Team,
Directors: TANAPA, DW,TAWA,
Conservator, NCAA,
Conference Sponsors,
Distinguished Guests,
Conference Participants,
Ladies and Gentlemen

I am pleased to have this opportunity to officiate the closing remarks of the eleventh TAWIRI Scientific Conference. I am pleased to see a satisfying attendance of long-term scientists and other researchers from within and outside Tanzania. Your presence is highly appreciated and signifies your regard to TAWIRI and your commitment to wildlife conservation in general.

Ladies and Gentlemen,

I have personally been taking keen interest in all the presentations and interactions among wildlife scientists in and outside the conference rooms. For sure this is a good forum for experienced and upcoming scientists to exchange ideas and findings. Therefore, I would like to express my appreciation for TAWIRI to be able to organise this important event and get an opportunity to attend.

Ladies and Gentlemen,

The TAWIRI Scientific Conferences have consistently become popular and thus, attracting a good number of wildlife scientists from different parts of the world. On behalf of my Ministry, TAWIRI Board and Management team, I would like to thank you all for attending and participate in this important scientific forum.

Ladies and Gentlemen,

The theme of this conference is *‘People, Livestock and Climate Change: Challenges for Sustainable Biodiversity Conservation’ I am* confident that the wide spectra of presentations totaling 186, which focused on this theme, have generated new scientific findings and facts that can be translated into action by wildlife managers and decision makers. Equally, there have been a lot of constructive challenges raised by researchers to the management authorities and policy makers. Similarly, I ask the management authorities to make effective use of the research findings presented at this conference for sustainable conservation of wildlife resources.

Ladies and Gentlemen,

Allow me to remind you of the sub-themes discussed:
(1) Human – Wildlife interaction
(2) Wildlife ecology and ecological interactions
(3) Wildlife Disease, Zoonosis, One health and Ecosystem Health)
(4) Wetland and Water Resources Management, and;
(5) Ethnobotany and Vegetation Ecology

These have provided valuable information and therefore I urge all presenters to submit final papers for early production of the proceedings. I believe that the published proceedings of the 11th TAWIRI Scientific Conference will provide scientific information that will support conservation of wildlife resources to not only Wildlife Managers who attended this conference but also to those who had failed to physically attend the conference.

Ladies and Gentlemen,

Once again on behalf of TAWIRI, I would like to give my sincere thanks to the sponsors of this conference specifically, my Ministry of Natural Resource and Tourism, Tanzania National Parks, Ngorongoro Conservation Area Authority, Tanzania Wildlife Authority, Frankfurt Zoological Society, Otterlo Business Corporation, Grumeti Fund, The Nature Conservancy, Wildlife Conservation Society, OIKOS, GIZ, Tanzania Association of Tour Operations and Arusha International Conference Centre. We also thank them for their support and we hope that they will continue to support TAWIRI not only for conferences, but also in other activities of the Institute. I call on other organizations to emulate this spirit of supporting TAWIRI in all research activities and the coming scientific conferences. I once again would like to take this opportunity to thank you all for finding time to attend this conference here in Arusha. It is my hope that the outputs of this conference have met the expectations of everyone here.

Ladies and Gentlemen,

When we hold the twelfth Scientific Conference we would be happy to be with you again. In this regard, we would like to extend a word of invitation, not only to all who attended this year's conference but also your colleagues who could not attend this time.

Ladies and Gentlemen,

I hope that you have had an enjoyable stay in Arusha; 'the Geneva of Africa', Tanzania's Conference City and Headquarter of the East African Community. If you get time after this conference I urge you to visit our tourist attractions including Arusha National Park, Tarangire National Park, Manyara National Park and Ngorongoro Conservation Area to enjoy the magnifisant nature that God had endowed us with. I wish you a safe journey on your way back home and welcome again.

Ladies and Gentlemen,

With these few remarks, I wish you a Merry Christmas and a Happy New Year, 2018 and declare the Eleventh TAWIRI Scientific Conference officially closed.

THANK YOU FOR YOUR ATTENTION.

RESOLUTIONS FOR THE 11TH TAWIRI SCIENTIFIC CONFERENCE, HELD ON 06TH - 08TH DEC. 2017, ARUSHA INTERNATIONAL CONFERENCE

The Tanzania Wildlife Research Institute (TAWIRI) scientific conferences are biennial events that bring together scientists and other stakeholders from inside and outside the country to present their research findings related to wildlife conservation. This year's gathering marked the 11th scientific conference under the Theme: ***"People, Livestock and Climate change: Challenges for sustainable biodiversity conservation"*** with six subthemes:-***Human Wildlife Interaction, Wildlife Ecology and Ecological Interactions, Wildlife Diseases Zoonoses and Ecosystem Health, Wetland and Watbringer Resources Management and vegetation ecology and Ethnobotany.*** The theme primarily aimed at contributing to global efforts towards sustainable wildlife conservation. The conference was held from 6th -8th December at Arusha International Conference Center (AICC) and brought together more than 300 participants. A total of 186 oral and posters, as well as several symposia addressing the main conference themes were presented. Most of presented papers addressed the prevailing wildlife management challenges and proposed their mitigation measures. In particularly, they focused on rapid human population growth, a need of improved land use, livestock encroachments in protected areas as well as the increased adverse impacts of climate change on biodiversity conservation. Recommendations proposed from this conference are expected not only to improve conservation of wildlife in the current era of increasing anthropogenic challenges, , but also to strategize better approaches that ecosystems services could be sustainably utilized for improvement of local livelihood

KEY RESOLUTIONS FROM THE CONFERENCE

Due to the conference uniqueness and its contribution in wildlife conservation, the following resolutions were drown:-

i. **Poaching as a major threat on wildlife:** Participants urged the Ministry of Natural Resource and Tourism and Management Authorities to take effective measures at all levels to prevent, combat and eradicate the illegal harvest of wildlife resources that has significantly contributed to the loss of biodiversity in the country.

ii. **Involvement of all key sectors during the conference**: Strongly advised TAWIRI and the Ministry at large to engage all key stakeholders in biodiversity conservation and should be part of all subsequent conferences, as the conservation of wildlife cut across many sectors such as mining, water, livestock, agriculture etc.

iii. **Support wildlife research within the country**: Strongly encouraged and urged all key stakeholders (TANAPA, WD, TAWA, NCAA, COSTECH, TFS, and the Ministry at large) to fully support TAWIRI on its daily research activities by allocating fund for wildlife priority researches within the country.

iv. **Give priority to more remote areas on wildlife research**: Urged Researchers to diversify research areas from northern circuits to western and southern circuits where very little has been done in terms of research while losses of biodiversity is too high.

v. S**pecial targets for less studied species**: Strongly encouraged researchers to diversify their research topics from the most studied species to less studied ones in the country.

vi. **Protect wildlife corridor and dispersal areas**: Strongly recommended the Ministry of Natural Resource and Tourism (MNRT) to spearhead the process of safeguarding wildlife corridors, dispersal areas and buffer zones for preventing biodiversity losses caused by increased habitat loss and blockage of wildlife corridors. Furthermore, the conference urged the need of promoting land sharing concept in human-dominated landscapes in order to improve iconservation of wildlife species residing outside the protected areas or during migration.

vii. **Proper campaign/measure to prevent zoonotic diseases**: Urged all wildlife management authorities and key stakeholders to critically identify, monitor and mitigate rapid spread of the emerging zoonotic diseases that had impacted both wildlife and communities adjacent protected areas. Find and create a special campaign/programme for awareness creation to communities adjacent the protected on means and how they can prevent the spread of the diseases.

viii. **Protection of endangered and threatened species**: Strongly urged management authorities to review species specifics conservation plans specifically for the threatened and endangered species of both flora and fauna. More efforts to should be done to reduce poaching for safeguarding the fauna populations (especially keystone species such as elephants, rhinos, lions, etc.)

ix. **Support village land use plans adjacent protected areas**: Strongly urged the Ministry to seriously support the initiatives and development of village use plans adjacent protected areas to reduce the impacts on land use changes that is associated with high increase of human populations in adjacent protected areas. By doing so it will support sustainable and alternative livelihoods for communities that are affected by wildlife conflicts through engagement of the communities and enhancing them with the rights and capacity to manage and benefit from wildlife.

x. **Mitigate human-Wildlife Conflicts:** Livestock keeping and farming are the major drivers of human-wildlife conflicts in Tanzania. The conference urged MNRT together with the relevant management authorities to strengthen vigilance, review and enforce legal system, empower local communities (WMAs), provide enabling environment for land use plans development and implementation, create awareness and education at all levels, create alternative livelihoods and sectoral linkages.

xi. **Climate change impacts on biodiversity**: Called upon researchers to seriously undertake research on various wildlife species and find out how climate change had impacted the particular species, and find possible mitigation measures for reducing the climate change impacts on biodiversity resources.

xii. **Capacity building and condusive environment for wildlife research**: Strongly argued both national and international donor to set aside funds for university student to attend to subsequent TAWIRI conferences to enrich themselves on knowledge generated from the same. Urged Donors to continue supporting TAWIRI in both financial and research equipment.

xiii. **The need for rewilding of ecosystems**: Both Protected Areas and Human-based areas are necessary, but neither are sufficient for conservation. All ecosystems change continuously such that static boundaries will not solve conservation problems. What is included now will not be in 100 years' time. The conference recommended the development of a quantitative approach to ensure long-term conservation of biodiversity through rewilding of ecosystems. Unless we refocus conservation on making human landscapes more suitable for biodiversity (rewinding of ecosystems) we will lose most of it this century.

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ACKNOWLEDGEMENTS

Tanzania Wildlife Research Institute (TAWIRI), is grateful to the Government of Tanzania, conservation authorities, institutions, organizations and companies for the financial support that made the 11TH TAWIRI Scientific Conference successful. The Institute acknowledges their valuable contributions and request them to continue supporting TAWIRI to achieve the same in the future.

Special thanks for the TAWIRI Board of Directors for their support and good directives, also to all the Conference Organizing Committee members who worked tirelessly to make the event possible.

TAWIRI wish to recognize the support from the conference sponsors whose logos are shown bellow:-

ASSESSMENT OF MACROINVERTEBRATES DISTRIBUTION AND DIVERSITY IN MZINGA RIVER, DAR ES SALAAM

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ABSTRACT

The assessment of macroinvertebrates distribution and diversity with the allied environmental variables were investigated in Mzinga River, Dar es Salaam in January 2014. Samples were collected from lower, mid and upper stream reaches with varying anthropogenic influences. Results suggest a positive correlation between macroinvertebrates community and water quality parameters measured. One-way ANOSIM revealed that, upper stream reaches had higher macroinvertebrates than mid and lower reaches ($P < 0.001$; Global R-value = 0.981). Pair-wise comparisons between stream reaches revealed significant difference ($P = 0.008$) in macroinvertebrates abundances. Species richness and diversity were higher in upper than mid and lower stream reaches (Randomization test, Delta-0.718; $P < 0.05$). Correlation of environmental variables and biological datasets was carried out using BIOENV procedure which identified pH, temperature, salinity, dissolved Oxygen, turbidity, electrical conductivity, phosphate and nitrates as variables significantly contributing to the observed abundance and distribution of macroinvertebrates in the study site. A single variable which significantly contributed to the observed structuring of macroinvertebrates was dissolved oxygen ($r = 0.677$), while a combination of five variables were dissolved oxygen, turbidity, salinity, nitrates and phosphates ($r = 0.951$) for upper, mid, lower stream reaches. Water quality plays significant role for the life of macroinvertebrates in aquatic systems. It is recommended that suitable management of point and non-point pollutant sources from anthropogenic activities be implemented in the study area, and laws and legislations be enforced for the better management and conservation of aquatic environment and its biodiversity.

Keywords: *Distribution; diversity, macroinvertebrates, , Mzinga River, water quality.*

INTRODUCTION

Rivers are important in sustaining organisms and ecosystems as their sources of water and habitat for aquatic lifeforms. Rivers have unique form and functions resulting from processes and interactions which occur along its four dimensions (Vannote *et al*., 1980). Good water quality is imperative in conservation of biodiversity. Rivers also support myriad number of people both in rural and urban areas who use water for domestic, transportation, and recreation, production of hydroelectric power, construction, agriculture and industrial purposes (Arimoro *et al*., 2011).

Varied anthropogenic activities performed along and within the rivers Bernhardt & Palmer (2007) and their basins present greatest threats to flora and fauna that live within and along the rivers, altering different biogeochemical cycles (Ojija 2015a) that lead to irreversible degradation of aquatic biota and ecosystem as well. Those threats include pollution from both domestic and industrial sources intensive agriculture which involves application of fertilizers and pesticides, sedimentation (Dudgeon *et al*. 2006) and invasive species. Other threats include deliberate modification of streams by building dams and reservoirs which alter the ecological characteristics of their basins (Walraevens *et al.* 2015) and climate change which increases vulnerability of biodiversity including macroinvertebrates.

Aquatic macroinvertebrates are organisms without backbone that live in water and can be seen with the naked eyes. They include all organisms with size more than 1mm living in aquatic ecosystems (Derleth 2001). They can be found on different microhabitats such as rocks, logs, cobbles, sediment, debris and aquatic plants during some period of their life. Macroinvertebrates include crustaceans, mollusks, aquatic worms and the immature forms of aquatic insects. Among the aquatic insects, Ephemeroptera, Plecoptera and Trichoptera (EPT) are pollution sensitive groups comprising of rich assemblages in low and medium order stony cobble streams (Shilla & Shilla 2011,) and can be used to determine conditions of aquatic habitats. EPT assemblages are mostly considered to be good indicators of water quality Johnson *et al.* (2011) due to its sensitivity nature. Benthic macroinvertebrates are most commonly used as biological indicators Ikomi et al (2005), since they are sensitive to environmental perturbations and therefore ease to gauge the health of environment in particular. Mzinga River presents a good opportunity to study the status of anthropogenic activities on benthic macroinvertebrates. The river originates on pristine area of Pugu forest reserve and then passes through areas having different anthropogenic activities, before draining into Mtoni Kijichi estuary. The present study assessed distribution and diversity of macroinvertebrates in Mzinga River.

MATERIALS AND METHODS

Study area

Mzinga River (Figure 1) is located within Dar es Salaam City located between latitude 6°52’0.00”S and longitude 39°16’60.00”E. General activities taking place along and within the river include agriculture, car wash, sand mining, water use for domestic purposes and industrial use for cooling machines on its lower course.

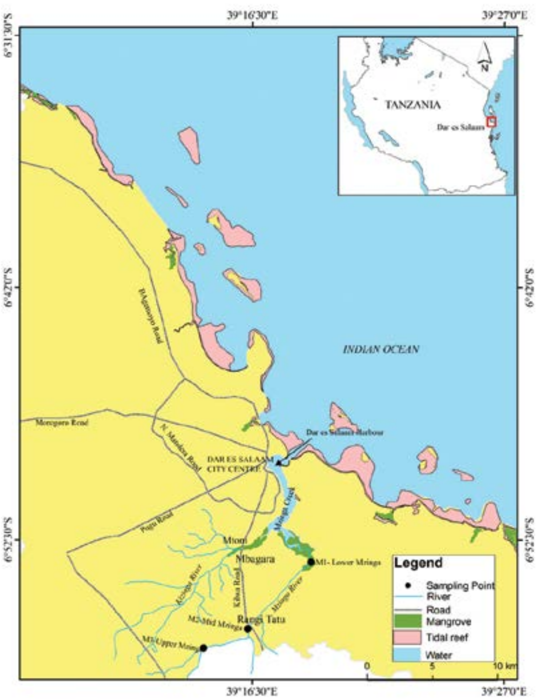

Figure 1: *Map of the study area indicating the study sites.*

Description of the study sites

Mzinga river system originates from the Pugu/Kisarawe hills and consists of sandy sediments supporting permeation that recharges the ground water favoring flow during the dry season. It stretches to about 10.4 km long with a catchment area of 40.72 Km^2. The water from Mzinga River is used for domestic purposes in Mbagala area in Dar es Salaam city. In this study samples were collected from the upper, mid and lower stream reaches of the river, characterized by varying degree of human influences. Mzinga upper stream reaches (M3) are less impacted by human activities due to its vicinity to Kazimzumbwi protected area and so is considered pristine unlike the mid and lower stream reaches. The area has many riparian vegetation and leaf litter providing good habitat and food substrates to the aquatic organisms.

The mid reach of Mzinga stream (M2) in this study was located at the Kilwa road bridge. The main activity characterizing this area is car wash. Water for car washing is drawn from the river channel through pipes; in turn the untreated water from car washing enters the river system, thus affecting water quality. Mzinga lower stream reaches (M1) was distanced about 300m from the Mangrove area. In this area, rice and maize cultivation were the main activities around the river banks especially during rainy season. Water run-off from agricultural catchments contributes organic and inorganic chemicals to the river, thus increasing their nutrients loads. Livestock and human encroachment was observed in this area as they both depend on this river for water. Tramping of this area by human and livestock has enhanced erosion which contributed to sediment loads to the river with consequences on macroinvertebrates inhabiting the river.

Macroinvertebrates sampling and handling

Macroinvertebrates were collected at each stream reaches by using a 300µm mesh hand-net in order to get species list and their relative abundance (Shilla & Shilla, 2011). Habitats sampled included surface water, channels banks, and underbank-cut. The target point was disturbed by kicking to dislodge the invertebrates to flow in the direction where the mesh was set; five replications were done on each site to minimize errors. The samples were allowed to drain to get rid of organic debris, the rest of samples were transferred into an empty plastic container and preserved with 70% alcohol for laboratory analysis. Samples were collected within two consecutive days to minimize variations due to climatic and hydrological changes. In the laboratory macroinvertebrates were sorted, identified and classified to species level using microscope and identification guides and keys (Davies *et al.*, 1986). Patterns of macroinvertebrates richness and diversity were assessed using Species Diversity and Richness software version 4.1.2 (SDR4) (Seaby & Henderson, 2007). SDR4 software computes Shannon-Wiener Diversity index by using the formula:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where,

H': - Shannon's diversity index
S: - Total number of species in the community (richness)

pi: - Proportion of S made up of the i species

lnpi: - Equitability (evenness)

Water-quality measurements

Water samples for the measurement of nitrate and phosphate were collected from each sampling point, kept in plastic bottles at low temperature (in a frosty container) and transported to the laboratory freezer. All water samples taken were analyzed a day after the field study. The measurements of physico-chemical parameters were done *in-situ* using calibrated (HORIBA U21XD, JAPAN). These parameters include: temperature, turbidity, salinity, dissolved oxygen, pH and electrical conductivity. Nitrate and phosphate were analyzed using spectrometric method and the reagents provided as proposed by Parsons *et al*., (1989).

Data analysis

A similarity of species among invertebrate samples collected from the three sampling points was determined using a PRIMER v6 package (Clarke & Gorley, 2006). Spearman correlation coefficient (r) was used to determine relationships among the total number of macroinvertebrates taxa, separate macroinvertebrates species and water quality parameters. One way- Analysis of Similarity (ANOSIM) was used to test for significant differences in macroinvertebrates abundance within the three sampling points. BIOENV procedure was used to determine which abiotic variables best explained the multivariate distribution of the macroinvertebrates communities. Statistical package employed for species diversity was Species Diversity and Richness (SDR 4) software version 4.1.2 (SDR4) (Seaby & Henderson, 2007) and Diversity Index used was Shannon-Wiener Diversity index. Randomization test were used to compare the significant different in diversity indices within three sampling points.

RESULTS

Macroinvertebrates abundance within Mzinga River

A total of 3623 macroinvertebrates individuals were collected within three reaches of Mzinga River. The upper stream reaches had highest number of macroinvertebrates (1567) followed by lower stream reaches (1107) and mid-stream reaches (949) (Figure 2*)*. Generally abundances of macroinvertebrates were dominated by *Dolophilodes distincus, Notonecta sp, Belostoma flumineum, Paraplea halei* and a lot of *Melanoides* which are pollution tolerant species and were found mostly at lower stream reach nearing the Indian Ocean (M1). This is the only site where Neritidae (*Neritina natalensis* and *Vittina natalensis*) are found, because their survival is mainly associated with oceanic condition. Mid- stream reaches (M2), were dominated by pollution tolerant groups e.g. Simulidae, Gomphidae, Oligochaeta and many Culicids but there were no stoneflies. On the other hand, the upper stream reaches (M3) were dominated by all species found in lower and mid -stream reaches with many mayflies, Caddisflies and stoneflies (pollution sensitive group) but with no Oligochaeta and Simulidae. Analysis of Similarities (one-way nested ANOSIM) revealed a significant differences ($p = 0.001$) in macroinvertebrates between the three reaches of Mzinga stream with the sample statistic (Global R) value of 0.981 (Table 1). Pair-wise comparison between the three stream reaches revealed significant difference ($p = 0.008$) within all stream reaches with R values as presented in (Table 2). Generally the separation of sites based on macroinvertebrates community composition between stream reaches was good as indicated by higher values of global R (Table 2).

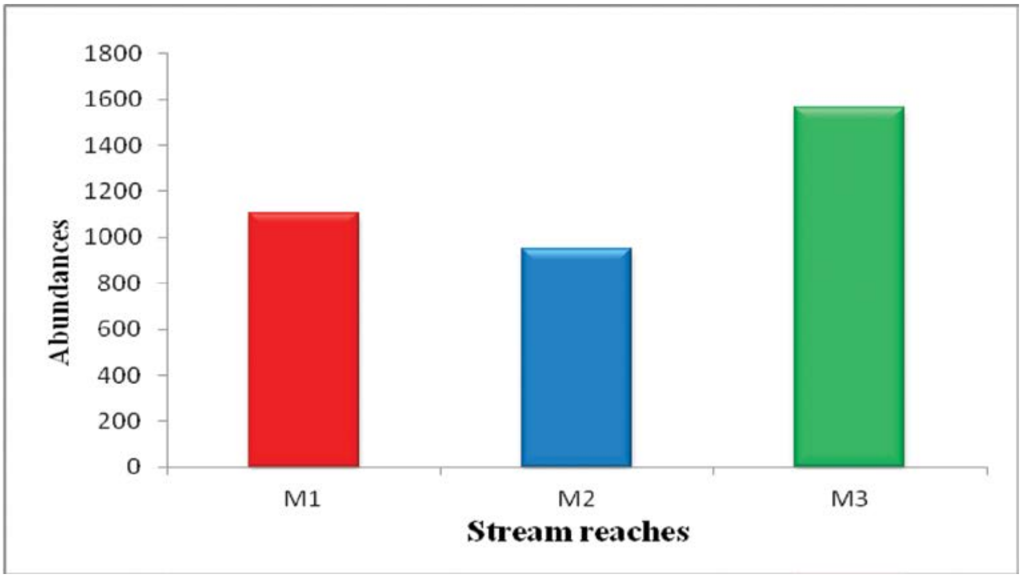

Figure 2. *Abundance of macroinvertebrates in Mzinga River at three stream reaches. (M1- Lower), (M2-Mid) and (M3-Upper stream reaches).*

Table 1. Comparison between macroinvertebrates abundance and studied site, using One Way ANOSIM. R = Sample statistic, p = probability, * = Significant.

Site	R-value	Sign. Level	p-value	Comments
Mzinga	0.981	0.1%	0.001	*

Table 2. Pair wise Comparison of macroinvertebrates abundance in Mzinga River in the three streams reaches using One Way ANOSIM. R = Sample statistic, p = probability, * = Significant and NS = Not significant.

Groups	R-value	Sign. Level	p-value	Comments
Lower vs Mid	0.986	0.8	0.008	*
Lower vs Upper	0.965	0.8	0.008	*
Mid vs Upper	0.919	0.8	0.008	*

Macroinvertebrates similarities within Mzinga River

Separation of sites based on macroinvertebrates between the three stream reaches was very clear as shown in the ordination graph (Figure 3). Cluster analysis clearly separated upper stream reaches from mid and lower stream reaches. Axis 1 in Figure 3 at the top left hand side was associated with higher counts of Mollusca (e.g. *Planorbis planorbis, Lymnae trancatula,*), Hemiptera (e.g. *Belostoma flumineum*) and Diptera (*Simulium sp*) with negative association. Since the upper part, was less polluted hence Ephemeroptera (*Ephemera simulans, Leptophlebia sp, Baetis capensis*), Coleoptera (*Anacaena globulus), Plecoptera (Clioperla clio, Isogenoides hansoni) showed positive association.* Moreover Annelida (e.g. Tubifex sp), Crustacean (*Deckenia mitis*) and Odonata (*Ophigomphus rupinsulensis*) were increasing towards the right hand side of the axis, which clustered mid and lower stream reaches (Figure 3; Table 3).

On the other hand Axis 2 was associated with higher counts of Hemiptera (e.g. *Paranisops incostants* (backswimmers), Mollusca (*Lymnae trancatula, Neritina natalensis*) Coleopteran (*Gyrinus natator*) to the right hand side of the axis where lower stream reaches found and other taxa like Annelida (e.g. *Tubifex sp*), Odonata (*Ophigomphus rupinsulensis*) and Diptera increases towards the right while Ephemeroptera and Plecoptera tends to decrease to the right hand side of the axis (Figure 3; Table 3) where lower parts was found, this indicate poor water quality on the study site.

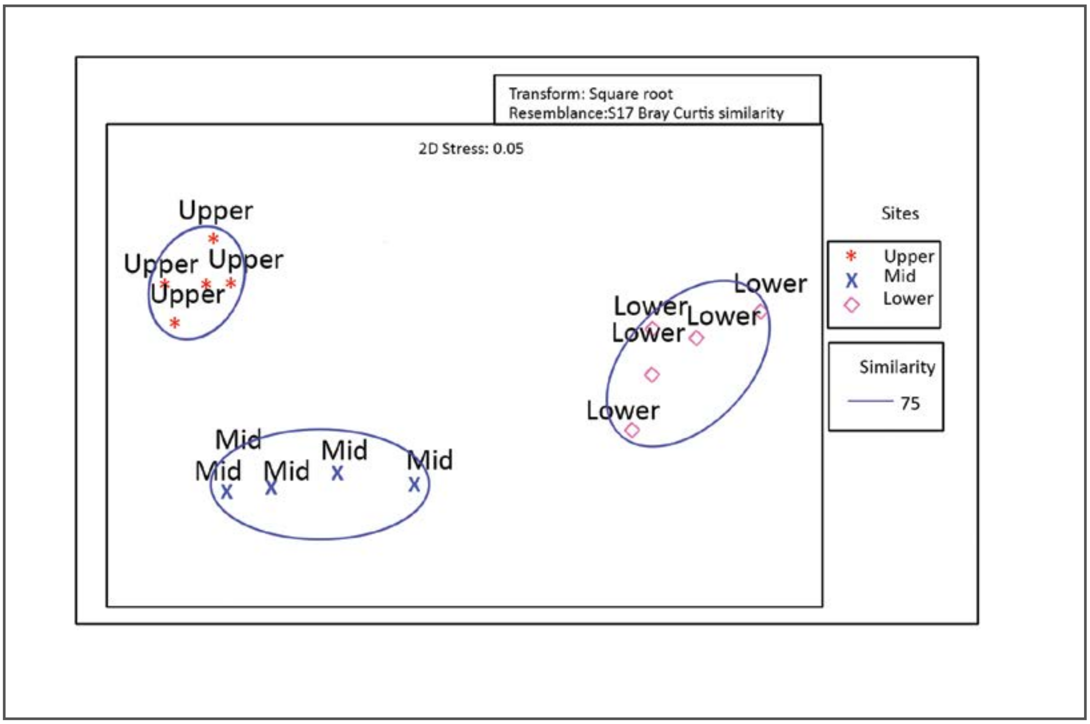

***Figure 3.** Ordination (NMDS) of Mzinga River based on macroinvertebrates samples. Site name and Stress value is indicated in the plot.*

Table 3. Non-metric Multi-Dimensional Scaling (MDS) ordination axes showing correlation statistics for macroinvertebrates groups in Mzinga River.

SPECIES	AXIS 1	AXIS 2
Planorbis planorbis	-0.99	-0.4
Belostoma flumineum	-0.97	-0.17
Ephemera simulans	0.95	0.49
Anacaena globulus	0.95	0.38
Radix auricularia	-0.93	0.23
Leptophlebia sp	0.92	0.34
Baetis capensis	0.88	0.56
Paranisops incostants	-0.65	0.98
Litobrancha revucata	0.81	0.53
Clioperla clio	0.69	-0.12
Simulium sp	-0.66	-0.41
Deckenia mitis	0.37	-0.85
Isogenoides hansoni	0.54	-0. 65
Gyrinus natator	0.49	-0.81
Ophigomphus rupinsulensis	0.21	-0.62
Neritina natalensis	0.2	0.79
Lymnae trancatula	-0.05	0.92
Tubifex sp	0.3	-0.26

Species richness within Mzinga River

A total of 156 macroinvertebrates species were collected in Mzinga site. Margalef's (D) index showed high species richness at the Upper stream reaches D = 8.835 compared with lower D = 6.705 and mid D = 5.981 stream reaches as shown in Figure 4. This complies with the anthropogenic activities carried out in the area, leading to only pollution tolerant group like Coleopteran and Diptera larvae to dominate the lower areas. High species richness in upper reaches was contributed with habitat quality and food availability that favor many species assemblages.

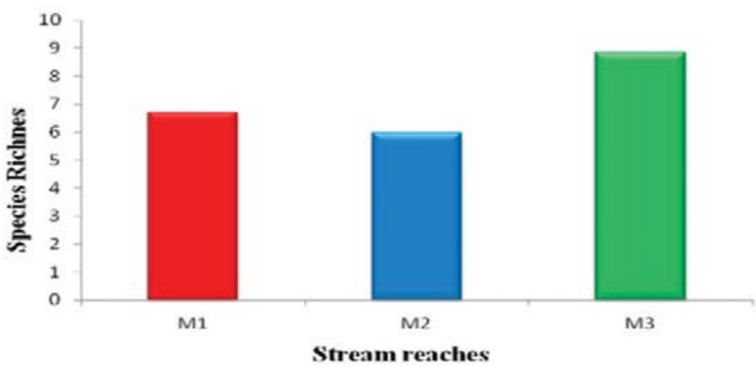

Figure 4. *Species richness within Mzinga River.*

M1 = Lower stream reach,

M2 = mid-stream reaches and

M3 = uppers stream reaches

Macroinvertebrates species diversity within Mzinga River.

Macroinvertebrates species Diversity indices (Shannon-Wiener H') at three stream reaches within Mzinga were as follows: H' = 2.876 for lower, H' = 3.042 for mid and H' = 3.315 for upper stream reaches (Figure 5). Randomization test for significant difference between indices showed significant difference along three stream reaches as summarized in Table 4.

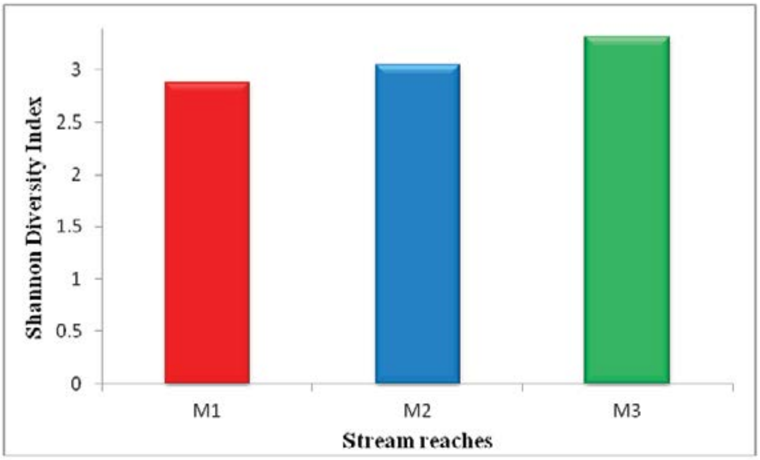

Figure 5. *Diversity (Shannon-Wiener index H') at three stream reaches in Mzinga River. M1 = Lower stream reach, M2 = mid -stream reaches and M3 = Uppers stream reaches*

Table 4. Pair wise comparison of the macroinvertebrates species diversity within Mzinga River, Difference between indices (Delta), P = Probability, * = Significant, ns = Not Significant

Sites	Delta Value	Sign. level	p value
M1and M2	0.16445	0.03%	0.0003*
M1and M3	0.4396	3.58E-9%	3.58E-11*
M2 and M3	0.2751	1.23E-11%	1.23E-13*

Correlations of macroinvertebrates groups to environmental variables (BIOENV) within Mzinga River.

BIOENV analysis done on the Mzinga river on macroinvertebrates taxa showed that, the Single environmental variables which best correlated with the biota assemblages was dissolved oxygen (r = 0.677), a combination of two variable which best correlated with the biota assemblages was dissolved oxygen, temperature (r = 0.788) while a combination of three environmental variables which best correlated with the biota assemblages was conductivity, dissolved oxygen, pH (r = 0.801). A combination of more than three variables which best explained the assemblages of macroinvertebrates are presented in table 5.

Table 4: Pair wise Comparison of macroinvertebrates abundance in Mzinga River in the three streams reaches using One Way ANOSIM. R=Sample statistic, P=probability, *=Significant and NS=Not significant.

Groups	R-value	Sign. Level	P-value	Comments
Lower vs Mid	0.986	0.8	0.008	*
Lower vs Upper	0.965	0.8	0.008	*
Mid vs Upper	0.919	0.8	0.008	*

Generally, a combination of five variables found to strongly correlate with macroinvertebrates distributions observed in Mzinga River as showed by global R. Such variables as elevated dissolved Oxygen, pH, temperature, conductivity and nitrates have been associated with mid and lower stream reaches.

DISCUSSION

Relationship between macroinvertebrates within stream reaches

The abundance of macroinvertebrates taxa in this study was significantly different between the three stream reaches; macroinvertebrates abundance in upper stream reaches was high compared to mid and lower stream reaches. The difference observed was probably due to reason that Mzinga river in its upper part is considered pristine as it passes in less polluted area unlike its mid and lower reaches which passes in highly impacted habitats by both domestics, agricultural and car washing activities. As a result, pollution tolerant groups such as Annelida (e.g., Tubifex sp), Crustaceans (e.g., *Deckenia mitis, Deckenia imitatrix*) and Diptera (e.g., *Aedes sp, Simulium sp*) dominated stream reaches reflecting its poor water quality. On the other hand, the upper parts of Mzinga river which were less impacted had better water quality and supported co-existence of pollution sensitive and pollution tolerant groups such Hemiptera (e.g. *Lethocerus indicus*), Odonata (e.g., *Crenigomphus reinter*), Crustaceans (e.g., *Potamonautes sidneyi, Atya sp*) Plecoptera (e.g., *Polycentropus sp*), Trichoptera (e.g., *Dolophilodes distincus*), Molluscs (e.g., *Radix auricularia, Lymnae stagnalis*). This study demonstrates a pattern similar to the findings of (Hepp & Santos 2009) which reported high macroinvertebrates abundance in reference site compared two urban and agricultural sites. Authors attributed the higher abundance values to be the consequence of the input of organic materials in the water which affected macroinvertebrates composition.

A study by Mero (2011) on assessment of water quality and spatial distribution of the major pollutants in Ngerengere river catchment Tanzania reported decrease of macroinvertebrates abundances along the river continuum. In this study, pollution sensitive taxa such as Heptageniidae, Leptophlebiidae, Teloganodidae and Pyralidae dominated the upstream reaches of the stream while pollution tolerant families such as Chironomidae, Oligochaeta and Belostomatidae were found in lower stream reaches of the stream. Anthropogenic activities have been reported to significantly affect the composition and diversity of macroinvertebrates.

Macroinvertebrates community differences across stream reaches

From the hierarchical clustering and MDS ordinations among the three stream reaches, the first dimension appeared to represent a biologically meaningful gradient ascribing the lowest values to mid and lower stream reaches while the highest values were recorded for upper stream reaches. As seen from the taxa abundance plots, a shift in community composition from pollution sensitive to pollution tolerant among the three reaches of Mzinga River was evident. Large proportions of taxa found in upper reaches were few perhaps absent in the lower and midstream reaches especially pollution sensitive group e.g. EPT. A close association between the macroinvertebrates communities collected from mid and lower stream reaches as shown by an overlap in the ordination diagram (Figure 3) can be explained in terms of combined effects of pollutants received from midstream where car washing activities are practised, and the oceanic influence experienced in lower stream reaches which signifies poor water quality of the downstream reaches (Hooper *et al*. 2003). However, the upper stream reaches which was dominated by much pollution sensitive groups e.g. mayflies (Thraulodes sp, Leptophlebia sp) and stoneflies (Isogenoides sp, *Clioperla clio*) suggest good water quality (Pliūraitė 2007). The significant differences ($p = 0.001$) in macroinvertebrates community structure between the three stream reaches as revealed by the Analysis of Similarities (ANOSIM) reflect high impacts by human activities.

Relationship between biotic indices within stream reaches

Benthic macroinvertebrates species richness and diversity are known to be sensitive to habitat characteristics and accountable to the water quality characteristics. For these reasons, benthic macroinvertebrates have been used worldwide as biological indicators for assessment of water quality in rivers and streams (Barbour *et al*. 1999). In this study, macroinvertebrates species diversity (H’), EPT number and species richness indicated that variation in pollution status had an impact on the structure of macroinvertebrates communities of Mzinga River. This verity is supported by the results of the multivariate ordination which revealed differences in the distribution of macroinvertebrates communities in the study site. The higher species richness, diversity and EPT number examined in upper reaches compared to mid and lower can be explained on basis of differences in the intensity of anthropogenic activities. Mid and lower stream reaches had high human influence that use the riparian area for agricultural purposes as well as car washing activities; whose effluents enters the lower stream reaches .

A number of similar studies support these results. For example, a comparative study done by Pliūraitė (2001) on benthic macroinvertebrates communities in agricultural impaired streams in Vilnius, Lithuania demonstrated high species diversity and richness in a less impacted stream which mainly had high diversity of macroinvertebrates especially sensitive taxa such as mayflies and caddisflies unlike the dominance of Oligochaeta and chironomids in highly impacted stream reaches. Shilla and Shilla (2011) assessed the effects of land use (Bush, Pasture and Urban) on streams health by using macroinvertebrates and reported high macroinvertebrates richness and diversity in Bush sites compared to pasture and urban. Authors attributed high counts of EPT assemblages to the stable habitat favouring many species to survive in bush sites unlike pasture and urban sites with poor water quality where few species mainly *P. antipodarum* and Oligochaeta were recorded. Long-term pollution of Mzinga mid and lower stream reaches has led to migration or extinction of pollution sensitive taxa and the remaining tolerant taxa (Oligochaeta, Chironomidae) adapt to the stressful condition of water quality deterioration.

Relationship between water-Quality variables within stream reaches

Water quality plays important role in determining general assemblages of macroinvertebrates in their natural settings. In this study physico-chemical water parameters measured revealed positive correlation with macroinvertebrates abundance. Generally lower and mid -stream reaches had high contributions than upper stream reaches.

pH value was slightly high in mid and lower than upper stream reaches. The value recorded in mid and lower stream reaches was consistent with the highest temperature in the site. High temperature increases solubility of both organic and inorganic substrates hence raises the pH. Extreme values of pH can cause shift or death of aquatic macroinvertebrates. A pH between 7 and 8.5 is ideal for biological productivity while pH < 4 is harmful to aquatic life (Deekae et al. , 2010). pH changes with temperature and impacts on dissolved oxygen levels in water, which in turn affects biochemical and chemical reactions such as photosynthesis in water affecting macroinvertebrates and other aquatic faunas. pH values in this study indicated that the water from Mzinga river is neither acidic nor alkaline, which sounds good for macroinvertebrates survival.

Conductivity is determined by the availability of organic and inorganic substrate in water environments. Areas with high impacts of agricultural activities, domestic wastes and car washing had high electrical conductivity of water. The higher conductivities recorded in mid and lower stream reaches of this study reflect an increase in dissolved ions and therefore a reduction in water quality. High conductivity in mid and lower reaches of Mzinga River is probably due to agricultural and surface run-off unlike in the upper reaches which recorded low values. The pattern of conductivity observed in this study was consistent with the study of (Friberg et al. 2001), who recorded high conductivity in the lake outlet stream. Authors prescribed that pattern as due to anthropogenic impacts (e.g., factory effluent and sewage input), and that the sites supported the highest density of Chironomidae which are indicators of high levels of conductivity and pollution. High levels of conductivity, suspended solids and nutrients have detrimental effects to aquatic life since they tends to deplete the amount of dissolved oxygen in the area (Akan *et al*. 2009).

Dissolved oxygen is a molecule of O_2 that is dissolved into the water channel. Dissolved oxygen can get into the water in two ways, through atmospheric oxygen mixing into a stream in turbulent areas or by the release of oxygen from aquatic plants during photosynthesis. All animals need oxygen to survive hence fluctuation in oxygen concentration may affect species dependent on oxygen-rich water, like many macroinvertebrates species e.g. EPT taxa that, without sufficient oxygen they may die disrupting the food chain.

In this study high levels of dissolved oxygen were observed in the upper stream reaches may be due to less anthropogenic impacts. The association of low conductivity and high allochthonous inputs in waters supports a huge number of sensitive groups such as Mayflies, stoneflies and caddisflies. The lowest level of dissolved oxygen which were recorded in mid and lower stream reaches may be due to oil spills from the car washing activities. These habitats favored pollution tolerant species such as Chironomous sp and Tubifex sp that can survive in anoxic environment. These species mainly dominated in the mid and lower stream reaches Boulton et al. (1997) in his finding reported that streams in native forests yielded significantly higher mean dissolved oxygen and many pollution sensitive taxa than pasture sites which were dominated by Chironomidae and other pollution tolerant groups. Similar studies by Biervliet et al. (2009) reported a decrease of macroinvertebrates richness and diversity in streams with low dissolved oxygen.

Salinity variability in streams lead to varied distribution and composition of macroinvertebrates because some aquatic organisms such as beetles, dipteran flies, Lymnaidae and Hydrobiidae tolerate saline conditions while others cannot. Groups of organisms like stoneflies, mayflies, caddisflies and dragonflies are generally sensitive to even minor increases in salinity (Clunie *et al.,* 2002). Crustaceans are generally thought to be relatively tolerant to salinity although some species are quite salt-sensitive, the highest salinity readings in this study were observed at the lower stream reaches while mid and upper reaches had almost similar salinity values. We postulate that this high value at the lower stream is probably due to influence of Indian Ocean in addition to agricultural run-off. Moreover, Mollusks were dominant in the lower stream reaches but very limited in the mid and upper stream reaches of the study site. In their study, Rutherford and Kefford (2005) found that the salinity of the stream in sites close to the coastal area was high compared to sites far from the coastal area; and Clunie *et al*., (2002) added that tolerance level to salinity within macroinvertebrates do vary from species type and life stages, where younger life stages may be more sensitive than mature stages and *vice versa.* Generally extreme salinities, pH and electrical conductivities tend to add to the toxicity effects of nutrients such as phosphates and nitrates leading to impairment of aquatic life and macroinvertebrates in particular, as observed high pH and conductivity at lower stream reaches of this study.

High turbidity in lower and mid- stream reaches in this study high pollution levels due to wastes from domestic wastes, sediment loading from agricultural fields Quinn *et al,.* (1997) and with the dye effluents from KTM industries. In studying the major components of textile industrial effluent, Yusuff *et al.*, (2004) identified dyes as some of the major pollutants of river waters that could increase turbidity. High variations of color and turbidity with season make them good indicators of temporal variations of water quality. High turbidity in water tends to inhibit light penetration in water which inversely affects photosynthesis process leading into lack of oxygen to aquatic organisms. This may lead to death of some aquatic fauna such as Mayfly, stonefly and pulmonate snail which cannot tolerate environments with limited oxygen supply.

Temperature in this study was almost similar with a slight variation between the stream reaches. The observed similarity was probably because the study was conducted in single dry season of the year. The slight higher readings were recorded in lower stream reaches. Reduction of riparian vegetation due to cultivation contributed to the elevation of temperature in the study sites since riparian vegetation reduces the amount of solar input and thermal radiation reaching the stream channel. Higher stream temperatures can reduce the stream's oxygen carrying capacity and therefore the dissolved oxygen which is valuable for aerobes. Higher temperatures can adversely increase the rates of organic decomposition and thus influence the rate at which nutrients are released from suspended sediments. The high temperature levels observed in lower stream reaches of Mzinga River can be associated with the removal of riparian vegetation due to frequent cultivation along the stream channels such as vegetable gardening. Several studies Shilla & Shilla (2012) in addition to present study, have reported that urbanization and agriculture had an effect of reducing shade which in turn elevates temperature in streams. Also (Quinn *et al.*, 1997, Shilla & Shilla 2011, Shilla & Shilla 2012) found elevated temperatures in urban and pasture stream compared to bush streams with corresponding decrease in macroinvertebrates assemblages in urban and pasture streams than bush stream. For example, the study by Shilla & Shilla (2012) reported that mayfly *Deleatidium autumnale* and stoneflies being susceptible to higher temperatures tended to decrease in numbers or even disappear in sites (urban, pasture and agricultural) where sources of pollution were introduced while the snail *Potamopyrgus antipodarum* being tolerant to pollution flourished. Lack of pollution sensitive taxa in lower stream reaches in this study suggest that among other factors, higher water temperatures may have disfavoured these taxa from surviving (Hepp & Santos 2009).

Higher nutrients mostly have negative effects on some macroinvertebrates as they stimulate algae and other aquatic plant growth which in turn depletes dissolved oxygen in stream water, affecting sensitive macroinvertebrates to survive. Nitrates and phosphates were high in lower than mid and upper stream reaches. The observed high nitrate and phosphate in lower stream reaches in Mzinga river in the current study and the corresponding lack of pollution sensitive macroinvertebrates taxa especially stoneflies in these sites Shilla & Shilla (2012) is supported by a number of studies which highlights that nitrogen and phosphorous are the major nutrients from agriculture fields and industrial effluents threatening river water quality. High nitrate levels in water are the result of organic materials collected from agriculture fields and urbanized watersheds during the rainy season (Sankar *et al.*, 2009).

Linkage of macroinvertebrates assemblages to environmental variables

The BIOENV procedure was used to identify which fundamental environmental variables best correlated with the observed community patterns. The variety of factors presumed to control macroinvertebrates communities in this study were temperature, pH, conductivity, dissolved oxygen, turbidity, salinity, nitrates and phosphates. Although variations of these parameters between stream reaches makes it difficult to establish the precise causes, BIOENV procedure results indicated that a combination of temperature, pH, conductivity, dissolved oxygen, turbidity, salinity, nitrates and phosphates were mostly important in the observed distribution of macroinvertebrates across the three stream reaches.

These physico-chemical properties play a vital role in shaping the distribution of macroinvertebrates in the three stream reaches studied. It is evident that changes in these variables can be attributed by a variety of human disturbances e.g. agricultural, domestics and car washing in the examined streams. In lower and mid-stream reaches the high number of pollution tolerant groups like Diptera e.g. *Chironomous sp, Simulium sp* and Annelida e.g. *Tubifex* signifies poor water quality compared to upper stream reaches which is still inhabited by pollution sensitive groups e.g. mayflies, caddisflies and stoneflies reflecting good water quality. According to Maul *et al.,* (2004) streams with the lowest total phosphorus and nitrates concentration had the greatest abundance of mayflies and caddisflies. This fact reflect the case of upper stream reaches of Mzinga river which had high counts of EPT assemblages unlike lower and mid- stream reaches.

Less sensitive species (*Chironomidae* and Oligochaeta) which were more abundant in lower and mid-stream reaches are generally known to prefer smaller low dissolved oxygen, high conductivity, salinity and high temperature (Jowett *et al*., 1991). The differences in salinity, turbidity and nutrients among stream reaches also have the potential to influence macroinvertebrates distribution by altering the supply and nature of food source entering the stream ecosystem. Change in environmental variables, particularly moving from upper to mid and lower stream reaches where intense human interference were observed in the present study can affect the type of organic matter present in a stream. High temperature, phosphates and nitrates in Mzinga lower stream reaches leads into inhospitable habitats leading to decrease perhaps shift of macroinvertebrates. The lower and mid-stream reaches of Mzinga River had less dissolved oxygen and high salinity compared to the upper stream reaches which correlated with abundance and diversity of macroinvertebrates. Therefore the difference in anthropogenic activities between stream reaches has the potential to influence macroinvertebrates distributions and function by changing the supply and nature of food source in the stream ecosystem.

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UNCOVERING THE OUTSTANDING AMPHIBIAN DIVERSITY AND ENDEMISM OF THE UDZUNGWA ESCARPMENT

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ABSTRACT

A remarkable herpetofauna exists in the Uzungwa Scarp Nature Forest Reserve (USNFR; 200 km^2), with at least three anuran species (Nectophrynoides asperginis, N. poyntoni and N. wendyae) regarded as 'hyper-endemics' due to their extremely narrow ranges (< 1 km^2). The site is exceptional for its amphibian diversity even within the Eastern Afromontane biodiversity hotspot, but is experiencing increasing human pressure. This is the first study of the full range of amphibian species and ecological associations at this site, and indeed one of only a handful of ecological studies of amphibians anywhere in Africa. Data collection between 2013 and 2017 led to the discovery of three potential new amphibian species as well as new sites for Hyperolius kihangensis, previously only known from its type locality. Thirty-four amphibian morphospecies (14 genera, 9 families) were recorded across 21 sampling sites. Unfortunately, N. poyntoni has not been recorded since 2003 and is currently flagged as Possibly Extinct. Genetic analyses on historical samples have highlighted several putative species under the same taxonomic name in USNFR, resulting in misleading distribution ranges and related conservation status. Together, these results also show a higher biological diversity than previously estimated for this area. By combining molecular and ecological methods, the CHURA project aims to assess amphibian richness and distribution across USNFR to quantify extinction risk and produce an Action Plan to support the long-term management of the site's amphibian diversity.

***Key words**: Amphibians, conservation, endemic, phylogeny, Uzungwa Scarp*

INTRODUCTION

There is consensus that the Earth is undergoing the sixth great mass extinction event (Barnosky *et al.,* 2011), with the class Amphibia containing the greatest proportion of species at risk of extinction (40% of over 6,200 species assessed; IUCN, 2017). The extant amphibians are one of the most diverse radiations of terrestrial vertebrates, with over 7,764 species currently known worldwide (Frost, 2017). Although the rate of discovery of amphibian species seems to remain high, with about 50 new species described every year (IUCN, 2017), their conservation status has steadily deteriorated since 1980, mainly due to habitat loss or alteration, climate change and the spread of fungal pathogens such as *Batrachochytrium dendrobatidis* (Baillie *et al.,* 2004); these threats often act synergistically. While agents of amphibian decline have been well documented for some species and habitats (Stuart *et al.,* 2004), the amphibian fauna of many tropical regions has not yet even been documented, and only basic ecological information is available for most African species. Documenting amphibian diversity, species distribution and habitat associations, and understanding the causes of declines and extinctions within the group, are among the key strategies suggested by the IUCN Amphibian Specialist Group in order to assess the level of threat and to plan proper conservation actions. To date, organic conservation strategies for African amphibians are sadly lacking, with a few exceptions such as Cameroon, Madagascar and South Africa (A.S.G and A.S.A, 2017). Protecting priority species within natural systems of wider biodiversity relevance can play a crucial role in a broader conservation perspective, especially when these species presence influences community stability and resilience (Gascon et al., 2007).

The rate of endemism has been used, along with species richness and rate of habitat loss, to identify biodiversity hotspots and to assess areas of conservation priority (Mittermeier *et al.,* 1998; Myers *et al.,* 2000; Burgess *et al.,* 2007). Endemism (limitation in geographical distribution to a certain region or area) and rarity (narrow geographical range and/or locally low population abundance) are often useful to estimate a species' susceptibility to extinction, since highly localized species are intrinsically more likely to be affected by stochastic catastrophes and extinction events (Gaston, 1994). Indeed, narrow endemics have been subject to several historical extinctions, including the infamous case of the Kihansi Spray Toad *Nectophrynoides asperginis* (Weldon & Du Preez, 2004). The Eastern Afromontane Biodiversity Hotspot, stretching from Saudi Arabia and Yemen to Mozambique and Zimbabwe, is renowned for its remarkable phylogenetic diversity and narrowly endemic species (Gordon *et al.,* 2012). Over a quarter of this hotspot runs through Tanzania, including an area that stands out within the Eastern Arc Mountains for its remarkable density of endemic species, the Uzungwa Scarp Nature Forest Reserve (USNFR). This forest is home to a range of threatened species in different taxa such as the Udzungwa-endemic primates Udzungwa red colobus *Piliocolobus gordonorum* (Endangered) and Sanje mangabey *Cercocebus sanjei* (Endangered), the Abbott's duiker *Cephalophus spadix* (Endangered and endemic to Tanzania), the Eastern tree hyrax *Dendrohyrax validus* (Near

Threatened), the Rufous-winged sunbird *Cinnyris rufipennis* (Vulnerable, Udzungwa restricted), the Usambara Eyelash Viper *Atheris ceratophora* (Vulnerable, Eastern Arc endemic), the Uluguru Forest Snake *Buhoma procterae* (Vulnerable, Uluguru, Rubeho and Udzungwa restricted), the Eastern Arc Sharp-nosed Chameleon *Kinyongia oxyrhina* (Near Threatened, Eastern Arc endemic), *Nectophrynoides poyntoni, N. wendyae,* (both Critically Endangered and endemic to the USNFR) and *Hyperolius kihangensis* (Endangered and endemic to the USNFR). Rovero *et al.* (2004) have also stressed the importance of USNFR as a catchment forest that provides invaluable ecological services to the surrounding human settlements (e.g. water for electricity and for cattle, fisheries, agriculture and domestic use; tree roots preventing soil erosion; and collection of medicinal plant parts). Like other Eastern African forests, the USNFR is experiencing increasing human pressures (e.g. bush-meat hunting, small-scale logging, firewood collection and agriculture) and significant declines in local species abundance and biodiversity have already been recorded in larger vertebrates (Rovero *et al.,* 2010; Hegerl *et al.,* 2015; Rovero *et al.,* 2017). The survival of narrow-endemic amphibians in the wild is particularly at risk unless their natural habitat is preserved. The striking biodiversity value in terms of endemism along with the alarming number of threatened vertebrate species makes this area one of the highest-ranking sites of conservation concern within the Eastern Arc Mountains (Dinesen *et al.,* 2001; Rovero & Menegon, 2005; Rovero *et al.,* 2010).

Recent molecular studies have suggested important changes to the higher-level systematics of African anuran lineages (Frost *et al.,* 2006; Pyron & Wiens, 2011; San Mauro *et al.,* 2014), however, at the species level many names actually represent complexes of species which are slowly being disentangled (Gvozdik *et al.,* 2014; Loader *et al.,* 2015; Channing *et al.,* 2016). A number of projects have focused on amphibian diversity and distribution in relation to altitude in Eastern Africa (Menegon & Salvidio, 2005; Poynton *et al.,* 2006; Ngalason & Mkonyi, 2011) and remarkable effort has characterized the study of Eastern African amphibian phylogeny and phylogeography in recent years (Lawson, 2010; Loader *et al.,* 2014). Phylogeny is essential for the devising of a taxonomy that reflects the natural relationships between genera, species and populations, and a solid starting point for ecological studies in regions with high cryptism. A few studies have investigated amphibian distribution and richness related to habitat degradation and anthropogenic activities in East Africa (Zancolli *et al.,* 2014) but only a handful have looked into ecological predictors (Ngalason, 2005; Gardner *et al.,* 2007). Although the Udzungwa Mountains are among the best sampled blocks of the Southern Tanzanian mountains (Dinesen *et al.,* 2001; Lovett *et al.,* 2006; Bowkett *et al.,* 2014; Martin *et al.,* 2015), the herpetofauna in large areas remains unexplored and virtually no fine-scale ecological data are available for amphibians. Historically, herpetological surveys have only covered a tiny portion of the whole USNFR, however those surveys revealed a marked altitudinal species turnover as well as interesting differences in species occurrence between distant sites within similar altitudinal belts (Menegon & Salvidio, 2005; Seki *et al.,* 2011). Moreover, only the single-species study by Weldon and Du Preez (2004) has looked at the effect of human activities on any montane forest amphibians occurring in the Uzungwa Scarp Forest area. Given the global trend of new amphibian species discovered every year (IUCN, 2017), the marked differences in species composition between USNFR sites (Menegon & Salvidio, 2005), the high proportion of narrow-endemics constituting over 10% of all USNFR amphibians (Seki *et al.,* 2011), and with large portions of the forest still unexplored, we predict that amphibian diversity and endemism is actually much higher than is currently known for this area. The CHURA project ('Conserving Hyper-endemic Udzungwa Restricted Amphibians') aims to fill this gap by using genetic and ecological methods to assess the amphibian richness and distribution across one of the largest closed-canopy forests in the Udzungwa Mountains, to identify environmental correlates of key species, to quantify extinction risk and produce an Action Plan to support the long-term management of USNFR amphibian diversity.

METHODS

Study Area

The Uzungwa Scarp Nature Forest Reserve (USNFR; 7°39' - 7°51'S, 35°51' - 36°02' E) lies in the Udzungwa Mountains, at the south-western end of the Eastern Arc (EA) range in Tanzania (Fig. 1). The USNFR clambers over a series of isolated hills with steep slopes connecting the Kilombero Valley to the plateau on the top, across three Tanzanian districts (Mufindi, Kilolo and Kilombero). Extending from 300 m to 2,068 m a.s.l. for a total of about 200 km^2 it is one of the largest continuous forest blocks within the Eastern Arc Mountains and is mainly covered by closed canopy forest, although open montane wetlands are also relatively common at higher altitudes. Rainfall in the area ranges from 1,800 to 3,000 mm per year, higher altitudes (above 1,600m.a.s.l.) usually receive more rain, and earlier in the season, compared to the lower slopes. The rainy season starts in late November and ends in June with a peak in April. Water runs through the USNFR in the form of several permanent and many temporary streams. The great altitude range of the USNFR and the remarkable diversity of vegetation types (Shangali *et al.,* 1998) possibly account for its unique number of strictly endemic species. Rovero *et al.* (2004) estimated the density of EA endemics and near endemics in USNFR to be nearly seven times higher than that for the entire Eastern Arc. This forest is especially important in terms of herpetofauna: according to the literature, 33 amphibian species from eight families and 33 species of reptiles from seven families occur in the USNFR, of these 22% and 54% are endemic or near endemic to the Udzungwa Mountains and to the Eastern Arc, respectively (Menegon & Salvidio, 2005). Although the neighbouring Kihansi Gorge is not officially part of the USNFR, the two areas are thought to have been part of a continuous forest block until they got separated by deforestation activities which occurred in the 20th Century. The term 'Udzungwa Escarpment' will be used to refer to the area comprising the USNFR and the Kihansi Gorge. The most renowned amphibian of this area, the Kihansi Spray

Toad *Nectophrynoides asperginis*, is sadly famous as the first amphibian in Sub-Saharan Africa listed as 'Extinct in the Wild' (Weldon & Du Preez, 2004; IUCN, 2017). This toad is one of four anuran species (*N. asperginis*, *N. poyntoni, N. wendyae*, and *H. kihangensis*) that until 2013 were only known from very restricted areas (i.e. their type localities, measuring less than 5 km^2 each) within the Udzungwa Escarpment and therefore regarded as 'hyper-endemics' (Seki *et al.,* 2011).

Figure 2: *Map of the Uzungwa Scarp Nature Forest Reserve also showing the Kihansi Gorge area at the south-western end. (Modified from a map by Menegon & Salvidio, 2005).*

Data collection

Four field seasons were carried out in the USNFR between 2013 and 2017 for a total of 14 months, during the amphibian reproductive period in the short rains (November-March). All amphibians were surveyed, with emphasis on the key hyper-endemic species *N. poyntoni, N. wendyae* and *H. kihangensis*. We used Visual Encounter Survey transects, pitfall traps with drift fences, night and day searches, timed digging, opportunistic surveys and acoustic sampling to investigate a total of 21 sites (three historical and 18 new ones) across the full altitudinal range of the study area. All precautions were used (e.g. disinfection of boots and equipment between sites) in order to prevent the risk of spreading potential amphibian pathogens between surveyed sites. Genetic samples are crucial for reliable species identification and related ecological research, especially where discriminating between cryptic species based on morphological traits is difficult. Thus, toe clips and skin swabs were used in this study as these are among the least invasive methods to collect DNA from amphibians. A wide range of habitat environmental variables used in ecological amphibian studies describing weather conditions, microclimate, topography, vegetation composition and local environment were recorded for each species at the point of collection.

Data analysis

We analysed some USNFR historical samples stored at the Science Museum of Trento. DNA extraction was carried out following the DNeasy® Blood & Tissue Kit protocol (Qiagen). Fragments of the mitochondrial 16S gene were amplified by Polymerase Chain Reaction (PCR) using universal PCR primers (16S Forward primer 5'-CGC CTG TTT ATC AAA AAC AT-3' and 16S Reverse primer 5'-CCG GTT TGA ACT CAG ATC A-3') and PuReTaq Ready-To-Go PCR

Beads (GE Healthcare). All amplifications were conducted in 25 µl volume with 2.5 µl [10 nM] of each 16S primer, 16 µl distilled water, 4 µl DNA extract and 1xPCR bead. Amplification conditions consisted of 35 cycles of denaturation for 60 s at 94˚C, annealing for 60 s at 51˚C and extension for 90 s at 72˚C conducted with an Eppendorf MasterCycler (Eppendorf, Schönenbuch/ Basel, Switzerland). Each sequence obtained by Sanger method was then checked against the Genbank and NCBI databases by sequence BLAST search. We chose to work with mitochondrial 16S gene because of its wide availability in amphibian sequences stored in the above mentioned databases. Accession numbers for novel sequences generated will be deposited to GENBANK.

PRELIMINARY RESULTS

A total of 34 amphibian morphospecies (14 genera and 9 families) were recorded during fieldwork, four of which are new records for this area (*Afrixalus fornasini, Callulina sp., Chiromantis xerampelina, Hyperolius marginatus*), and at least three of which are likely new to science (see 'Undescribed species' section for further details). Table 1 shows a matrix of species recorded at each site, indicating their IUCN Red List status, altitude range, endemism and number of sites of occurrence within the Udzungwa Escarpment. Two of the five recorded USNFR-endemics (*N. wendyae* and *N. sp. nov. 1*) are only known from their type localities (≤ 1km^2). A species accumulation curve was generated using sample-based rarefaction (Mao's Tau) in PAST (Hammer *et al.,* 2001). This shows a gentle slope, suggesting that the number of species is expected to keep increasing, although the rate of new species discovery is slowing (Fig.2).

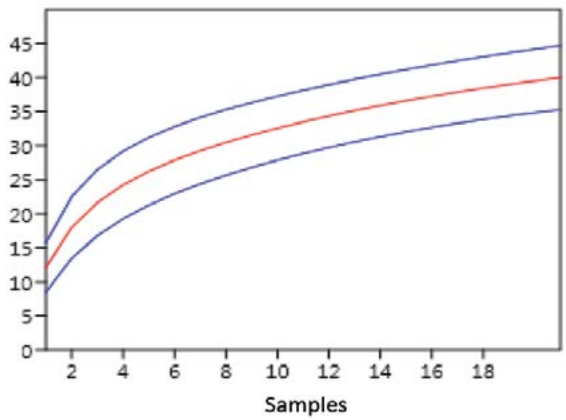

Figure 3: *Species accumulation curve (in red, 95% confidence intervals in blue) generated in PAST program using the sample-based rarefaction method (Mao's tau).*

New sites of occurrence were found for *H. kihangensis*, which was previously only known from its type locality; the presumed hyper-endemic is now known to co-occur with *N. wendyae* in at least one site. Although *Afrixalus morerei*, *Phrynobatrachus parvulus* and *P. uzungwensis* are known to occur in USNFR (Menegon & Salvidio, 2005), they were not encountered during this study. Unfortunately, regardless of repeated surveys, *N. poyntoni* (Critically Endangered) has not been seen nor heard calling either at its type locality or in other portions of the study site. As predicted by the lack of the very specific habitat needed by *N. asperginis* within USNFR, no individuals of this species were found in any of the surveyed sites either.

Undescribed species

Based on divergent morphological and bioacoustic traits we identified three toad species, putatively in the genus *Nectophrynoides*, as undescribed species new to science. These are: *N. cf. wendyae*

(Fig. 3a & b), *N. sp. nov 1* (Fig. 3c) and *N. sp. nov 2* (Fig. 3d & e). As we were surveying the Northern portion of the USNFR in 2016 we came across several individuals morphologically similar to *N. wendyae*, including many juveniles (Fig. 3b), which would suggest a much broader distribution of this narrow-endemic species, however, some morphological features were not entirely convincing. While the final proof will come from genetic results, closer examination of a collected specimen showed small but distinct differences compared to topotypical specimens of *N. wendyae*, leading us to conclude we are dealing with an undescribed species rather than a new population (*N. cf. wendyae*). These differences include visibly yellow hands, feet and upper lip, a different arrangement of spines on the body surface and the lack in all of the individuals encountered of the red throat typical of male *N. wendyae*. While *N. cf. wendyae* and *N. sp. nov* 2 were recorded at three and two different sites respectively, *N. sp. nov* 1 was only encountered in one locality and seems to be associated with waterfalls. The present evidence of an extent of occurrence smaller than 1km^2 suggests that this species could be another narrow-endemic. This latter amphibian is clearly morphologically different from any other known *Nectophrynoides*, especially for the presence of large spines covering the dorsum, head and limbs (Fig. 3c & d), although similar to *N. paulae,* which is restricted to the Mamiwa Kisara forest in the Ukaguru Mts.. Individuals of *N. sp. nov. 2* (Fig. 3e & f) instead are morphologically closer to *N. poyntoni* and *N. tornieri* but a

Phylogenetic relationships and genetic variability within the study area based on historical samples of USNFR amphibians

Preliminary molecular analyses on 60 historical samples, selected from the collection of the Science Museum of Trento, have shown there to be several putative species under the same taxonomic name in USNFR, which results in an even higher biological diversity than previously estimated. Available samples comprised nine genera, namely *Arthroleptis, Leptopelis, Nectophrynoides, Sclerophrys, Afrixalus, Hyperolius, Arthroleptides, Phrynobatrachus, Amietia*. According to the sequences of the target locus (16S), over one third (43%) of the samples do not match Genbank and NCBI database sequences at a reliable level (percentage of identical sites < 97%). This pattern is especially evident among the *Arthroleptis*, nearly 70% of which had a divergence level above 3%. Most of these specimens are morphologically similar and would be currently treated as single species (i.e. *Arthroleptis cf. affinis, A. cf. reichei, A. cf. xenodactyloides*). We considered *Nectophrynoides cf viviparus* as a putative species akin to *N. viviparus* because sequences from two historical specimens blasted over 5% dissimilar to topotypical individuals of the *N. viviparus sensu stricto*.

Anthropogenic impact

Recent signs of illegal human activities were clearly visible in most surveyed sites as well as along the main paths that cross the USNFR from the plateau to the Kilombero valley. We recorded operating snares (often along or next to the main paths), signs

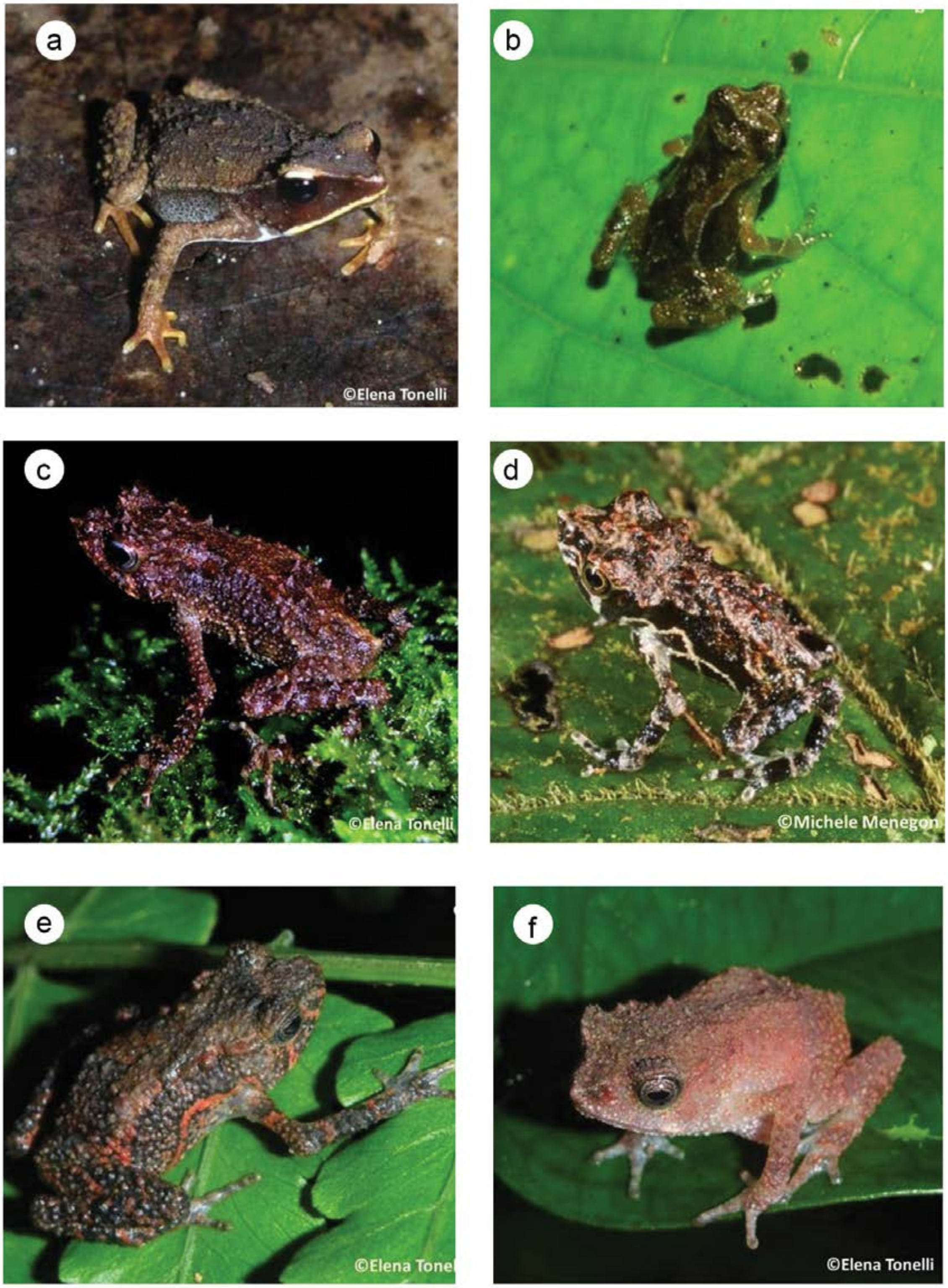

Figure 4: *Nectophrynoides cf. wendyae adult (a) and juvenile (b). Nectophrynoides sp. nov.1 adult (c) and juvenile (d) photographed at their only known locality in USNFR. Two individuals of Nectophrynoides sp. nov. 2 (e, f) at two different sites within USNFR.*

of illegal fishing, active poacher camps, signs of firewood and reed collection, freshly cut timber and regularly used small secondary paths; in two areas we have seen small cultivated vegetable patches and a localized sprouting pine field. We also noticed that the bark of specific trees had been collected, presumably for medicinal purposes. Whenever bamboo patches are present near the forest edge, like in the north-western portion of the Nature Reserve, bamboo sheath are collected by local farmers to weave thatched roofs for their field shelters. Local authorities were regularly informed of these findings in order for them to promptly take action. A highly impacting event of human origin occurred in November-December 2016 when fire affected several parts of the Southern USNFR. We recorded a patchy distribution of burnt sites at various altitudes from the Kilombero Valley up to at least 1,600 m a.s.l., especially along the main paths joining the valley to the highland villages of Ihimbo and Mbawi (Fig. 1). According to our observations, the fire mainly affected shrubs and bushes and most of the larger trees seemed to be slowly recovering, however many younger trees did not survive and the leaf-litter in burnt areas was completely wiped out.

DISCUSSION INCLUDING CONSERVATION IMPLICATIONS

Biodiversity

The Udzungwa Escarpment displays a remarkable amphibian diversity at all taxonomic levels, especially compared to larger forested areas such as Bwindi Impenetrable National Park (about 29 amphibian species in 331 km^2) or Kibale National Park (about 33 amphibian species in 766 km^2) in Uganda (Plumptre *et al.,* 2007). A total of seven morphospecies and two genera (*Callulina* and *Chiromantis*) have been added to the checklist, including three species presumably new to science based on their morphological and bioacoustic traits. These findings validate our hypothesis on the incompleteness of the previous amphibian inventory, while the positive slope shown by the rarefaction curve suggests that a few other species are yet to be listed. With eight species known to occur in the Udzungwa Escarpment (including *N. asperginis* and *N. poyntoni*), *Nectophrynoides* seems so far the most diverse genus in the area, however if we look from a genetic perspective the picture changes and the amphibian diversity of this area strikes as even more outstanding. The genus *Arhroleptis* shows a much higher radiation than expected from literature (four species)(Menegon & Salvidio, 2005). We claim that three *Arthroleptis* morphospecies appearing in Table 1 should be considered as complexes of several putative species or evolutionary significant units (ESU), on the basis of the genetic results obtained from the historical samples we sequenced. Specifically, our analyses identified *Arthroleptis cf. affinis 1* (occurring in two historical sites), *A. cf affinis 2* (three sites), *A. cf affinis 3* (one site), *A. cf affinis 4* (one site), *A. cf affinis* 5 (two sites), *Arthroleptis cf. reichei* (one site), *Arthroleptis cf. xenodactyloides 1* (one site), *A. cf xenodactyloides 2* (two sites), *A. cf xenodactyloides 3* (two sites); these lineages also display some bioacoustic differences. On this basis and including the species which were not recorded during this study but are known to occur in the

Udzungwa Escarpment from reasonably recent surveys (see Table1; Menegon & Salvidio, 2005; Mutagwaba & John, 2014), the full checklist of the area comprises at least 49 putative amphibian species (17 genera and 10 families). All together the herpetofaunal diversity in the Udzungwa Escarpment is remarkably higher than previously known and we expect this diversity to increase again once we will analyse all the genetic samples collected in the past four years.

Table 1- Checklist by family of all putative species known to occur in the Udzungwa Escarpment according to literature and original data.

Recorded species	IUCN Red List Category	Endemism	Nr of sites of occurrence in Udzungwa Escarpment	Altitude range in USNFR (metres a.s.l.)
Family Arthroleptidae				
Arthroleptis cf. affinis 1	-	-	-	-
Arthroleptis cf. affinis 2	-	-	-	-
Arthroleptis cf. affinis 3	-	-	-	-
Arthroleptis cf. affinis 4	-	-	-	-
Arthroleptis cf. affinis 5	-	-	-	-
Arthroleptis cf. reichei	-	-	14	590 - 1790
Arthroleptis stenodacytlus	LC	W	5	455 – 900
Arthroleptis cf. xenodactyloides 1	-	-	-	-
Arthroleptis cf. xenodactyloides 2	-	-	-	-
Arthroleptis cf. xenodactyloides 3	-	-	-	-
Leptopelis flavomaculatus	LC	W	2	590 – 740
Leptopelis grandiceps	VU	EA	15	1200 - 1960
Leptopelis parkeri	EN	EA	1	1650
Leptopelis uluguruensis	NT	EA	6	590 – 1415
Leptopelis vermiculatus	EN	EA	9	900-1650
Family Brevicipitidae				
Callulina sp.	-	-	1	1200
Probreviceps loveridgei	EN	EA	1	1560
Probreviceps rungwensis	EN	EA	2	1480 – 1650
Spelaeophryne methneri *	LC	EA	1	650 - 980
Family Bufonidae				
Mertensophryne micranotis *	LC	EA	1	650 - 980
Nectophrynoides asperginis *	EW	US	1	650 - 980
Nectophrynoides poyntoni †	CR	US	1	1200
Nectophrynoides tornieri	LC	EA	2	740 -1650
Nectophrynoides cf. viviparus	-	EA	2	1560-1610
Nectophrynoides wendyae	CR	US	1	1480
Nectophrynoides cf. wendyae	-	US	3	1560-1650

Nectophrynoides sp nov. 1	-	US	1	1650
Nectophrynoides sp nov. 2	-	US	2	1600-1650
Sclerophrys brauni	LC	EA	2	880-1550
Family Hyperolidae				
Afrixalus fornasini	LC	W	2	650 - 1200
Afrixalus morerei †	VU	EA	1	1800
Afrixalus sp.	-	-	2	1410 - 1490
Afrixalus uluguruensis	VU	EA	13	1480 - 1960
Hyperolius kihangensis	EN	US	4	1480 - 1760
Hyperolius marginatus	LC	W	1	590
Hyperolius minutissimus	VU	EA	7	1600 - 1960
Hyperolius mitchelli	LC	W	1	590
Hyperolius substriatus	LC	EA	13	650 – 1960
Family Petropedetidae				
Arthroleptides yakusini	EN	EA	7	450 – 1200
Family Phrynobatrachidae				
Phrynobatrachus sp.	-	-	2	590 - 880
Phrynobatrachus rungwensis	LC	EA	8	450 – 1650
Phrynobatrachus uzungwensis †	NT	EA	3	1100 - 1900
Phrynobatrachus parvulus †	LC	W	1	1800 - 1900
Family Ptychadenidae				
*Ptychadena anchietae**	LC	W	1	650 - 980
*Ptychadena mascareniensis **	LC	W	1	650 - 980
Family Pyxicephalidae				
Amietia tenuoplicata	LC	EA	17	450 - 1960
Strongylopus fuelleborni †	LC	EA	1	1800
Family Rhacophoridae				
Chiromantis xerampelina	LC	W	2	650 - 700
Family Scolecomorphidae				
Scolecomorphus kirkii	LC	EA	8	1410 – 1960

Lineages marked with a dagger (†) are cited in literature but were not encountered during data collection in 2013-2017. Lineages marked with an asterisk (*) are known to occur in the Kihansi Gorge but were never recorded in the USNFR. Endemism: Eastern Arc endemic or near endemic (EA), USNFR endemic (US), widespread (W). IUCN Red List Categories: Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in the Wild (EW); threatened categories are shown in red.

Endemism

It is important to point out the high proportion of endemic amphibians occurring in the Udzungwa Escarpment. Nearly 43% of the recorded morphospecies are EA endemics or near endemics and another 14% are endemic to the USNFR, resulting in a total of endemic species which surpasses the proportion of the more widespread amphibians (18%), even including the yet-to-be-assessed ones (25%). *N. sp. nov. 1* is regarded as narrow-endemic as it is only known from an area smaller than 1 km^2. This finding balances the downgrading of *H. kihangensis* from hyper-endemic to USNFR-endemic and keeps the number of range-restricted species in the Udzungwa Escarpment worthy of attention. The broader extent of occurrence, area of occupancy and altitude range (1,480-1,750m a.s.l.) for the above mentioned *Hyperolid* are quite encouraging for the survival of the species which appears less susceptible to stochastic localised extinction events. The increasing number of sites where the species has been found, up to 23 km away from the type locality, support the hypothesis that this species is actually more widespread within USNFR and suggests that its 'hyper-endemism' was an artefact of patchy sampling. An interesting note about *N. cf. wendyae* is that it was first found in 2015 during an opportunistic walk in an area that had thoroughly been surveyed within this project the previous year and that over the four years it was only recorded at this site during two out of four visits. It is possible that different climatic conditions affect the activity of this toad making its detection fluctuating with weather changes. It is unfortunate that, regardless of repeated surveys at *N. poyntoni*'s historical site in 2013-2016 and surveys of new sites in the past four years, we cannot confirm the persistence of this toad in the wild. Given that it has not been recorded since it was described in 2003, the species has been flagged by the IUCN as Possibly Extinct. Since the call of this amphibian is well known, a potentially successful approach could be the use of fixed sound recorders at the type locality to collect acoustic data in a similar way as a camera trap would do with images.

Anthropogenic disturbance and threats to survival

Over a quarter of the amphibian species recorded in the Udzungwa Escarpment are listed as Vulnerable (4), Endangered (6), Critically Endangered (2) or Extinct in the Wild (1) in the IUCN Red List of Threatened Species (2017). All illegal activities reported by other authors between 2004 and 2010 are still heavily ongoing (Rovero *et al.,* 2004; Rovero & Menegon, 2005; Rovero *et al.,* 2010). The main human pressure in the forested areas adjacent to the Kilombero Valley (<1,200 m a.s.l.) seems to be habitat degradation related to timber production and trade, although collection of firewood, charcoal pits and a small amount of poaching was also recorded; in Northern and North-western USNFR, instead, we noticed a mixture of bush-meat hunting (largely prevalent), small-scale agricultural encroachment and honey collection. Although none of the narrow-endemics' type localities (all above 1200 m a.s.l.) show high degrees of direct environmental disturbance (e.g. logging), illegal anthropogenic activities are clearly occurring in those areas and are likely to affect the ecosystem at some point in time. The above mentioned fire outbreak in 2016 is a good example, as fire can easily burst out as a consequence of honey collection for which smoke is regularly used to distract bees. While we are uncertain of the exact cause behind the fire and we know that the naturally thick leaf-litter along with the delay in the beginning of the rains provided the perfect conditions for it to spread quickly, local authorities confirmed the anthropogenic nature of this event. Although the situation was promptly tackled by the local army which managed to extinguish the fire at lower altitudes and none of the narrow-endemic sites were affected by this dramatic event, this kind of episodes highlights the extreme vulnerability of slow-moving range-restricted species to any destructive stochastic occurrence and the crucial need for enhanced protection in the USNFR.

In conclusion, the USNFR clearly hosts a high cryptic diversity, especially evident in certain lineages and further analyses are needed to understand phylogenetic relationships and conservation value across the USFNR. Discriminating between cryptic species will be crucial for any future ecological work and to establish an effective management plan for the site's amphibian diversity. The remarkable biodiversity of this area deserves prompt and proper conservation actions, both for its wildlife and to protect the ecosystem services it provides, particularly in the light of the ongoing threats and increasing human demand.

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STATUS, PATTERNS AND COMPOSITIONS OF WILDLIFE ROAD KILLS ON GRAVEL ROAD NETWORKS IN SERENGETI ECOSYSTEM, TANZANIA

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ABSTRACT

Roads have important adverse effects on wildlife, such as natural habitat fragmentation and degradation and direct killing of fauna, which leads to reductions in wildlife population size. Though, wildlife populations are susceptible to road kills even along the current existing gravel roads, however little information is available in many protected areas including that of the Serengeti ecosystem. This study employed the longitudinal study design and direct observation method to document the status, patterns and compositions of wildlife road kills on the existing gravel road networks passing through the Serengeti ecosystem. Our results revealed that a total of 51 individual's wildlife road kills belonging to 26 species (19 birds, 7 mammals) were recorded. More animals were found killed during the morning (70.6 %) than afternoon (29.4 %) session in the area. In addition, birds were the more affected taxa (31, 60.8%) than mammals (20, 39.2%). Furthermore, the African hares (Lepus capensis) on the mammals' side and helmeted guinea fowl (Numida meleagris) on the birds' side were the major victims of wildlife road kills in the area. Therefore, this study recommends for strengthening of fines, establishment of vehicle speed limit check points, and installation of speed limit devices (e.g. solar powered cameras) to prevent further loss of wildlife in the area. Furthermore, stakeholders and management authorities are advised to adhere to protected areas regulations.

Key words: *Wildlife road kills, gravel roads, session, conservation, Serengeti ecosystem.*

INTRODUCTION

Roads that 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). Moreover, road conditions, traffic volume, poor visibility and speed accelerate the road kill incidences (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 wildlife 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 (Puglisi *et al*., 1974; Clevenger et al., 2001; Joyce and Mahoney, 2001). In addition, the wildlife 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). Hence, understanding the species or vertebrate communities that are susceptible to road-kill is important for their sustainable conservation. Though, there is much data onwildlife road kills in some protected areas in Tanzania (Drews, 1995; Kioko *et al*., 2015a)**,** little information has been documented in the Serengeti ecosystem (Lyamuya *et al* 2016; Nkwabi *et al*. 2018). Therefore, this study aimed at investigating the status, spatial-temporal patterns and compositions of wildlife road kills on the existing gravel road networks in the Serengeti ecosystem by hypothezing that: (1) The number of individual wildlife species killed differed in the area. (2) More wildlife road kills would be found during the morning session because some of them might have been killed during the night. (3) Wildlife road kills do not occur randomly in the area but are spatially clustered because wildlife movements tend to be associated with specific habitats, terrain, and adjacent land use types (Puglisi *et al*., 1974; Hubbard et al., 2000; Clevenger *et al*., 2001; Joyce, 2001).

MATERIALS AND METHODS

Study area

The study was conducted in the Serengeti ecosystem, northern Tanzania. It extends to south-western Kenya between 1^0 and 3^0 S and 34^0 and 36^0 E covering an area of approximately 30,000 km^2 (Fig.1). The Serengeti ecosystem has about 70 larger mammal species (McNaughton, 1985; Sinclair & Arcese, 1995) and more than600 avifauna species (Nkwabi *et al*., 2015; Nkwabi, 2016), and supports one of the largest herds of migrating ungulates and the highest concentrations of large predators in the world (Sinclair & Arcese, 1995).

Its high animal species diversity 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, typically below 600 mm per year (Homewood et al., 2004). The area receive bimodal rainfall, short (November-December) and long (March-May) seasons. However in some years inter-annual variations are inevitable especially due to effects of climate change. The woodland area is occasionally interspersed with patches of tall open grasslands and receives an annual maximum rainfall of 1100mm per year (Norton-Griffiths et al., 1975). 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), whichare dominated the intermediate grasslands and woodlands. The topography is highly variable, with catena effects having important influences on woody species.

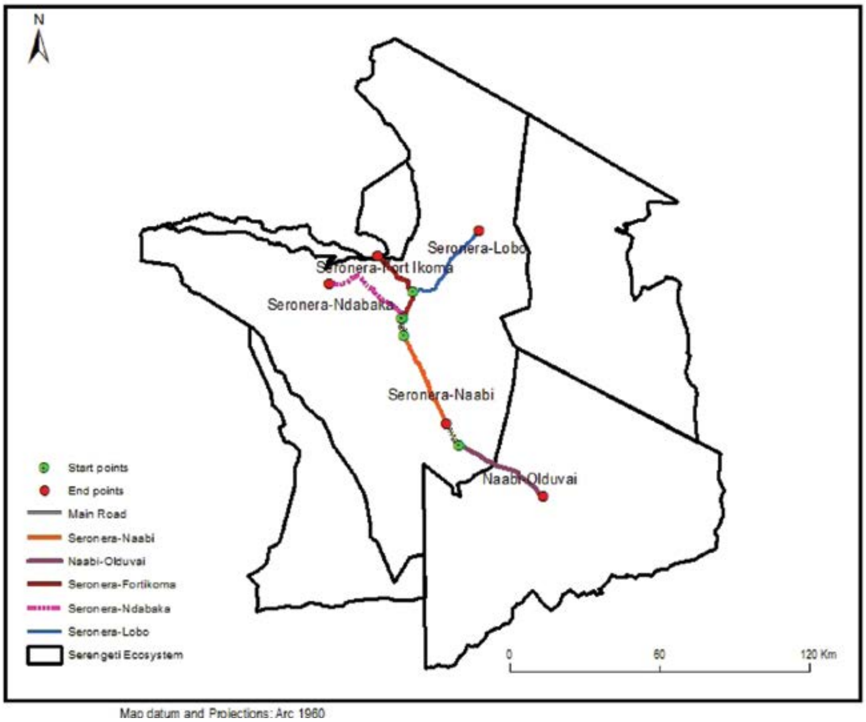

***Figure 1**: Sketch map of the Serengeti ecosystem showing the study transects along the main roads*

Data collection

The survey was conducted in wet (March-April 2015) and dry (July-August 2015) seasons. We performed morning (7:30-11:30am) and afternoon (2:00-6:00pm) sessions of wildlife road kill detection for all selected transects. 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 including; (i) Naabi-Olduvai, (ii) Seronera-Naabi, (iii) Seronera-Fortikoma, (iv) Seronera-Ndabaka and (v) Seronera-Lobo. Observations along each road transect considered three sections, the left-hand edge, the center of the road, and right-hand edge. Nine sampling points established at 5km interval. The targeted species were all vertebrates from four taxonomic groups (mammalian, birds, reptilian and amphibians). Prior to commencement of data collection the vehicle odometer was set to zero and recorded 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 recommended by Collinson et al. (2014) and 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 or an injured animal was spotted, it was identified, the GPS location, time, carcass condition, number killed.

estimated age class, sex, and habitat type were recorded in a standard form. Also the animal killed or injured was photographed for close identification. After collecting all required data from the carcass, it was removed away from road to avoid double counting. The equipment used for data collection included a ranger finder; measuring tape, weather station device, camera, speed gun, mobile freezer, post mortem kit and GPS.

Data analysis

Statistical Package for Social Science (SPSS, version 16.0) software was used for analyzing the data. The data were found normally distributed using Kolmogorov's test. Descriptive statistics was used to summarize the data. While t-test was used to compare whether there was any significant difference between variables. Hence, in all tests, $p \leq 0.05$ was considered statistically significant.

RESULTS

The status and vulnerability of wildlife road kills in the Serengeti ecosystem

Our results revealed that a total of 51 wildlife road kills were observed comprising 26 species including 7 mammals and 19 birds' species (Table, 1). Birds were more affected species (31, 60.8%) than mammals (20, 39.2%, Table, 2).

Table 1: Showing the species of animals killed in the area

Species	Common name	Order	Family	Scientific name	No. kills
Birds	Fisher's sparrow-lark	Passeriformes	Alaudidae	Eremopterix leucopareia	1
	Grey-backed fiscal	Passeriformes	Laniidae	Laniusexcubitoroides	1
	Red-Capped lark	Passeriformes	Alaudidae	Calandrella cinerea	1
	Ring-necked dove	Columbiformes	Columbidae	Streptopelia capicola	3
	Secretary bird	Charadriiformes	Sagittariidae	Sagittarius serpentarius	2
	Helmeted guineafowl	Galliformes	Numididae	Numida meleagris	6
	Chestnut-bellied sandgrouse	Charadriiformes	Pteroclidae	Pterocles exustus	2
	Crested francolin	Galliformes	Phasianidae	Francolinus sephaena	1
	Croaking cisticola	Passeriformes	Cisticolidae	Cisticola natelensis	1
	Lilac-breasted roller	Coraciiformes	Coraciidae	Coracias caudata	2
	Speckle-fronted weaver	Passeriformes	Ploceidae	*Sporopipes frontalis*	1
	Superb starling	Passeriformes	Sturnidae	*Lamprotornis superbus*	1
	Brown-cronedtchagra	Passeriformes	Malaconotidae	*Tchagra australis*	1
	Flappet lark	Passeriformes	Alaudidae	*Mirafrarufocinna-momea*	2
	Coqui francolin	Galliformes	Phasianidae	*Francolinus coqui*	2
	Grey-brestedspurfowl	Galliformes	Phasianidae	*Francolinus rufopictus*	1
	Rattling cisticola	Passeriformes	Cisticolidae	*Cisticola chiniana*	1
	Grey-capped social weaver	Passeriformes	Ploceidae	*Pseudonigritaarnaudi*	1
	Red-checked cordon blue	Passeriformes	Estrildidae	*Uraeginthus bengalus*	1

Mammals	Warthog	Artiodactyla	Suidae	*Phacochoerus africanus*	1
	Thomson gazelles	Artiodactyla	Bovidae	*Gazella thomsonii*	5
	Diki-dik	Artiodactyla	Bovidae	*Madoqua kirkii*	1
	African hare	Lagomorpha	Leporidae	*Lepus capensis*	9
	Bat-eared fox	Carnivora	Canidae	*Otocyon megalotis*	1
	Wildebeests	Artiodactyla	Bovidae	*Connochaetes taurinus*	2
	Silver-backed jackal	Carnivora	Canidae	*Canis mesomelas*	1

Spatial-temporal patterns of wildlife road kills in the Serengeti ecosystem

Results showed that wildlife road kills differed significantly between transects (t = 15.867, df = 50, p < 0.001) whereby 35.3% of road kills were found in the Seronera-Fortikoma, 23.5% in Seronera-Ndabaka, 13.7 % in Seronera-Lobo, 21.6% in Seronera-Naabi and 5.9% in the Naabi- Oldupai transect (Table 2, Fig.2).

Table 2: Showing the number of wildlife road kills in different transects in the area.

Species	Transect name: Seronera -Naabi	Naabi -Olduvai	Seronera - Lobo	Seronera - Ndabaka	Seronera -FortIkoma	Total
Birds	5	3	3	8	12	31
Mammals	6	0	4	4	6	20
Total	**11**	**3**	**7**	**12**	**18**	**51**

A logistic regression with animal category (birds & mammals) as dependent variable found only session (B= -2.228, Wald = 6.067, p = 0.014) was significant independent variable in explaining which type of the animal category was mostly killed in the area (x^2= 13.790, df = 6, p = 0.032, Negelkerke R^2= 0.321). Transect name, season, road and habitat did not add any significant value in explaining this variation. More animals were found killed during the morning (70.6 %) than afternoon (29.4 %) session and their differences were statistically highly significant (t = 20.083, df = 50, p < 0.001). Generally, wildlife road kills occurred more during dry and high tourist season (64.7%) (July to August) than in wet and low tourist season (35.3%) (March to April) and their differences were statistically highly significant (t = 24.371, df = 50, p < 0.001). Birds' road kills (74.2%) were more recorded during the dry season than mammals (50.0%). African hares (*Lepus capensis)* (n = 9, 17.6%) on the mammals side and Helmeted guinea fowl (*Numida meleagris)* (n = 6, 11.8%) on the birds side were the major victims of wildlife road kills in the area (Table 1). More adults wildlife species (n = 47, 92.2%) than sub adults (n = 3, 5.9%) and juveniles (n = 1, 2.0%) were found killed in the area (t = 57.435, df = 50, p < 0.001). The overall wildlife road kills occurrence differed significantly between habitat types (t = 12.556, df = 50, p < 0.001), with the highest frequency (39.2%) in wooded grassland (Fig.3).

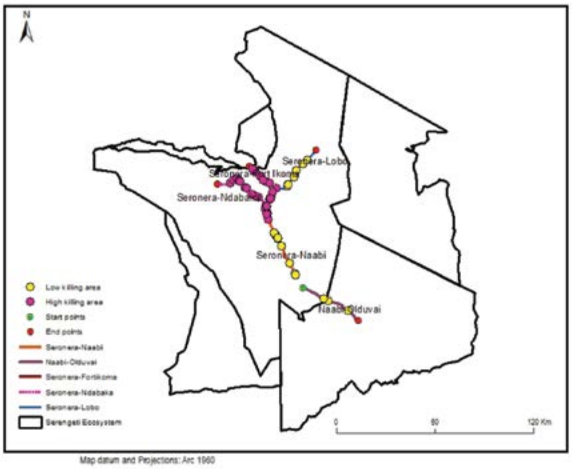

Figure 2: *A map showing the magnitude of wildlife road kills observed along the selected main gravel roads in the Serengeti ecosystem.*

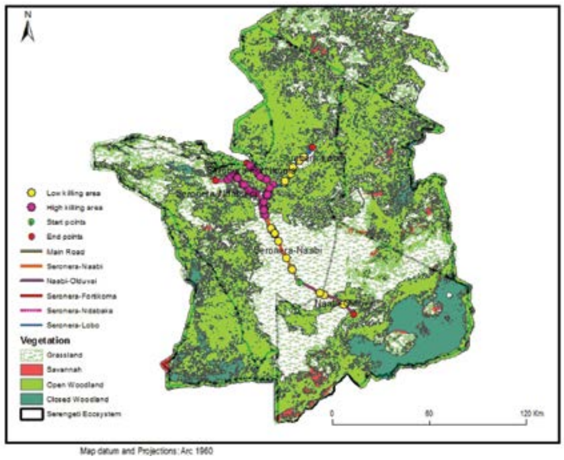

Figure 3*: Proportion of wildlife road kills sighted between different habitats in the Serengeti ecosystem.*

DISCUSSION

Status and vulnerability of wildlife road kills in the Serengeti ecosystem

Though globally, there is increased scientific interest in wildlife road kills and road ecology but very few studies have been conducted in Serengeti ecosystem (Lyamuya *et al*. 2016; Nkwabi *et al.* 2018), even though wildlife road kills have the potential to significantly affect biodiversity of the area. In our findings, the wildlife species found killed in our study supported our hypothesis that the number of individual wildlife species killed differed significantly in the area. Therefore, confirming the existing gravel roads networks in the Serengeti ecosystem has adverse effects on wildlife species viability in the area. Also, supported what previous studies have found that roads traversing through protected areas have adverse impact on wildlife (Bissonette & Kassar, 2008, da Cunha *et al*. 2010, Gerow *et al*. 2010, Santos *et al*. 2011, Selvan *et al*. 2012, Kioko *et al.* 2015a). The majority of killed animals were small to mid-sized mammals, which were especially susceptible to this type of road suggesting the possibility that they might avoid collisions if the road were narrower or drivers drove slower (Griet *et al*. 2016). However, our results have increased our understanding on the species or wildlife communities that are more susceptible to road-kill in our case the African hare on the mammals' side and helmeted guinea fowl on the birds' side to ensure their proper conservation in the area. Therefore, supporting what previous studies have found that wildlife that are often hit by vehicles are those which are attracted to spilled grain, road side plants, insects, basking animals, small mammals, salt liking or dead animals (Forman & Alexander, 1998; Freitas *et al*., 2013).

Spatial-temporal patterns of wildlife road kills in the Serengeti ecosystem

Our study also revealed that more wildlife species were found killed during the morning than afternoon session which supported our hypothesis that wildlife road kills would be found more during the morning session because some of them might have been killed during the night due to poor visibility. Moreover, wildlife road kills were recorded to occur more on the wooded grassland part of the area because of poor visibility for the victims to detect the passing vehicles, therefore supporting what previous studies have found that forest adjacent to roads increases the number of ungulate collisions (Griet *et al*. 2016). Also, this finding supported our hypothesis that wildlife 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 (Puglisi *et al*., 1974; Hubbard *et al*., 2000; Clevenger *et al*., 2001; Joyce and Mahoney, 2001).

Precisely more wildlife road kills occurred during the dry season than in wet season reflecting the expected seasonal pattern as observed by previous study (Dussault *et al*., 2006). In our case birds' road kills were more recorded during the dry season than mammals supporting what previous studies have found that differences in composition and species abundance of road kills are related to season and to habitat selection (Griet *et al*., 2016). However, on the daily basis the morning sessions indicated a higher detection of wildlife road kills probably because animals are more active in the morning concurrent with high traffic volume and some might have been killed during the night.

CONCLUSIONS AND RECOMMENDATIONS

Our study concludes that the existing gravel road networks have adverse impacts on the wildlife species in the area. However, the findings reported here may be underestimated due to the fact that some carcasses could have been missed (uncounted) and some may have been removed by other people and/or scavengers (Slater, 2002). Despite of that our findings have increased our understanding on which wildlife species and high risk zones to enable both conservationists and managers to concentrate their mitigation actions in the area. Also, our findings have increased our understanding that there is a need to improve and integrate science and environmental licensing to mitigate wildlife mortality on existing gravel roads networks in the area.

From these findings we therefore recommend that further investigation on the ecology and behavior of helmeted guinea fowl and African hares on the gravel road networks of Serengeti ecosystem should be carried out. Also, we call for strengthening of fines, establishment of the vehicle speed limit check points, installation of speed limit devices (e.g. solar powered cameras) and informs the tour drivers about the problem to be aware.

ACKNOWLEDGEMENTS

This project was funded by Tanzania Wildlife Research Institute (TAWIRI) and permission for conducting the research was obtained from TANAPA. This study could not have been possible without the co-operation of all the Serengeti Wildlife Research Centre (SWRC) staff. Special thanks go to Chief Park Warden of the Serengeti National Park for the logistic support during our data collection period.

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ABUNDANCE AND HABITAT DISTRIBUTION OF BLACK AND WHITE COLOBUS MONKEYS (COLOBUS GUEREZA) IN SUB-AFROMONTANE FOREST OF OLMOTONYI, AREUMERU DISTRICT

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ABSTRACT

This study intended to assess abundance and habitat distribution of the C. guereza in submontane forest of Olmotonyi. Stratified sampling was used to divide the study area into three strata which are often visited by these monkeys. Data on abundance of C. guereza were collected through line transect censuses method in which every member of a population was counted. Coordinates for every preferred habitat of the C. guereza were recorded by using GPS hand held receiver for habitats mapping. Also direct observation during the day time was used to obtain data on feeding behavior of the Colobus. A morning count was considered as one observation period which gave out the total number of Colobus found at the study area. The map showing the habitats of C. guereza was drawn using Quantum GIS program. Results revealed that, there is only one group of C. guereza found in the study area which consists of 11 Colobus living in a social group of three classes. Moreover, results revealed that monkeys area found in Jacaranda-Newtonia habitat found around administration premises, Albizia-Croton habitat found along the riverine forest and Albizia-Jacaranda habitats found in the arboretum forest. Moreover, C. guereza were found to feed on leaves, flowers, twigs and fruits of different trees. These include: Jacaranda mimosifolia, Ficus benjamina, Syzygium cuminii and Newtonia buchananii due to availability of young leaves, flowers, fruits and twigs for both dry and rain season. Therefore, conservation efforts should be given to conserve the only remained habitats and trees species to ensure sustainability of these rare monkeys around the study area.

Keywords: *Abundance, habitats and feeding behavior*

INTRODUCTION

Colobus monkeys (*C. guereza*) is found in lowland and montane tropical moist forest, and gallery forest in montane forests of Mt. Kilimanjaro and Meru, and the adjoining forests at slightly lower altitudes (Kahe; Momela Lakes in Arusha National Park), Tanzania and Kenya (Fashing and Oates, 2013). This species is threatened in parts of its range by habitat loss through deforestation for timber, conversion to exotic forest plantations and conversion to agricultural land (von Hippel *et al*., 2000). The Mount Kilimanjaro *C. guereza* is considered to be endemic to northeast Tanzania, occurring on Mount Kilimanjaro and Meru (Fashing and Oates, 2013), with smaller populations in the forest patches of lower south Mount Meru (Grove *et al*., 2007) These include

Forestry Training Institute (FTI), Olmotonyi campus and Themi Forest Reserve. *C. guereza* is well known for its ability to persist, sometimes at high density, in small, isolated, disturbed, forest patches (Fashing and Oates, 2013). Landscape fragmentation is severely impacting populations of colobus living outside the Park in areas like FTI (von Hippel *et al*., 2000). This paper is primarily concerned with presenting the abundance and distribution of *C. guereza* in the lower slopes of Mount Meru landscape. The information from this paper could be used by conservationists to develop conservation interventions for these rare species.

MATERIAL AND METHOD

Study Area

The geographical location is for FTI campus is 3º15'S 36º 45'E . Found approximately 20 km North of Arusha City. The elevation range from 1500 to 3000 meters above sea level. Climate is generally cool with distinguished seasons. From July to October the area experience cold weather and from November to December experience short rains. Hot month's start from March to June long rains is experienced. Dry season starts from July to October. Mean annual temperature stands at 20 to 17ºc. The vegetation is Montane forest dominated with *Alibizia gumifera, Croton megalocurpus, Cussonia spicata*, *Ficus spp, Makaranga capensis, Ocotea usambarensis and Podocarpus falcatus* which are found along the riverine forest.

Data collection

Stratified sampling was used to divide the study area into three strata (riverine forest, arboretum forest and administration premises which are often visited by monkeys. Then, from each stratum line transect censuses method was employed to assess abundance of *C. guereza* in which every member of a population was counted. This was successfully conducted through monitoring the groups observed during the early morning. Coordinates for every preferred habitat of the *C. guereza* were recorded by using GPS receiver for habitats mapping. Also direct observation during the day time from morning to evening was used to obtain data on feeding behavior of the *C. guereza* in the study area.

Data analysis

Microsoft excel was used to summarize the abundance of *C. guereza* from the three strata. To produce a map showing the distribution of *C. guereza,* GPS coordinates were uploaded into Quantum GIS to delineate current suitable habitats for the *C. guereza*. To get the percentage of food item from main plant species the C. *guereza* feed, each food item of main plant species was summed in excel and then the percentage of each food item was computed.

RESULTS AND DISCUSSION

Abundance of *Colobus guereza*

During this study, it was observed that, there is only one group of *C. guereza* monkeys found in the study area which consists of Eleven (11) Colobus monkeys living in a social group of three classes based on their size from physical appearance. Five (5) were of middle age class (youth), one (1) was of small age class (baby) and other five (5) were of bigger age class (parents). The results are in line with Groves (2008) who reported that the black and white colobus live in social groups of three to fifteen individuals while Landes (2000) in a groups of 8 to 15 individuals.

Distribution of *Colobus guereza*

From the figure 1 below, there are three common habitats for *C. guereza* maped from the study area. These include; *Jacaranda-Newtonia* habitat found around administration premise, Western part of the study area, *Albizia-Croton* habitat found along the riverine forest, Southern part of the study area and *Albizia-Jacaranda* habitats found around arboretum forest, Northern part of the study area. The *C. guereza* monkeys were observed shifting periodically within these habitats as their tradition of interchanging their diets simply because the habitats contain different tree species which are highly preferred by them. The structure of habitats comprised tall trees where these monkeys use as their sleeping habitats during the night and abudant food tree species in which the monkeys prefer to feed. Another possible reason *C. guereza* monkeys prefer such habitats is because the area is in sub montane zone with relatively cool and moist conditions. Elsewhere, Jensz and Finley (2011) reported that *C. guereza* prefer riparian, moist lowland, rain forests, swamp forests and sometimes in plantation forests.

Feeding behavior of *Colobus guereza*

During the assessment and observation, *C. guereza* found to prefer eating leaves, flowers, twigs and fruits of different trees (Table 1). The highly preferred species were *Jacaranda mimosifolia* (100%), *Ficus benjamina* (75%), *Syzygium cuminii* (75%) and *Newtonia buchananii* (75%). The results are in agreement with literature which indicated that leaves constitute 78-94% of the *C. guereza* diet followed by fruits and a small percent of leaf buds, blossoms, bark and wood, seeds, flowers, petioles, arthropods, water-plants and soil which constitute 2–6% (Champman *et al*, 2007).

Table 2 : Shows the food diversity and diet of Colobus.

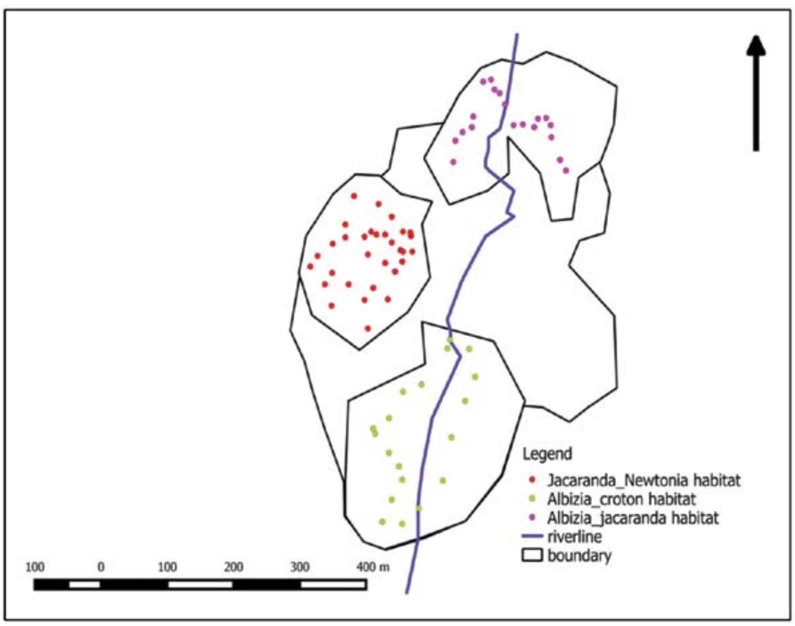

***Figure 5**: A Map showing habitat distribution of C. guereza in the study area*

S/N	Species name	Food diversity Parts of tree fed Leaves	Flowers	Fruits	Twigs	Percentage per tree (%)
1	*Jacaranda mimosifolia*	1	1	1	1	100
2	*Albizia gumifera*	1	1	0	0	50
3	*Widdringstonia nodiflora*	0	0	0	1	25
4	*Ehretia cymosa*	0	0	0	1	25
5	*Olea capensis*	1	1	0	0	50
6	*Ficus benjamina*	0	1	1	1	75
7	*Newtonia buchananii*	1	0	1	1	75
8	*Vitex keniensis*	0	1	0	0	25
9	*Erythrina abysinica*	0	0	0	1	25
10	*Bridelia micronatha*	0	0	0	1	25
11	*Duranta erecta*	1	0	0	0	25
12	*Syzygium cuminii*	0	1	1	1	75
13	*Croton megalocurpus*	0	0	0	1	25
14	*Eucalyptus saligna*	0	1	0	0	25
15	*Brachychton rupestris*	1	0	0	1	50
16	*Calodendrum capense*	1	1	0	0	50
	Percentage per tree parts (%)	43.75	50.00	25	62.5	181.25

CONCLUSION AND RECOMMENDATION

The study revealed that, there is only one group of *C. guereza* found in the study area which consists of 11 members living in a social group of three classes based on their size from physical appearance. The study further recorded three main habitats for *C. guereza* in the study area and the distribution is species and diet dependent following the abundance and preferences of food. Species highly preferred were *Jacaranda mimosifolia*, *Ficus benjamina*, *Syzygium cuminii*, and *Newtonia buchananii* due to the availability of young leaves, flowers, fruits and twigs during the data collection. Although *C. guereza* is reasonably well protected in the forest reserves and national parks where it occurs. Conservation efforts should be given to conserve the only remained habitats and trees species to ensure sustainability of these rare monkeys around the study area.

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BREEDING ECOLOGY OF KORI BUSTARD ARDEOTIS KORI STRUNTHIUNCULUS IN THE SEENGETI NATIONAL PARK

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ABSTRACT

The breeding ecology of the Kori Bustard was studied in the plains of the Serengeti National Park, Tanzania in 2014 and 2015. Random transects were used to search for male courtship displays, nests, chicks and sub-adults. GPS satellite collars were fitted and used to locate nesting females. Linear regressions analyses were used to determine the predictors that contributed most to the variation of the dependent variables (courtship display, nest, chicks, sub-adults). The results indicate that courtship behaviour peaks during the short dry and short rainy season before the peaks in nests and chicks. The highest nest frequency was found in short grass habitats. Female Kori Bustard may undergo repeated nestings within a single breeding season. The adult sex ratio was male-biased during the nesting period. The Kori Bustard-breeding season in the Serengeti plains is relatively long, lasting almost for nine months, and taking place during all seasons except for the long dry season. It was recommened that management authorities assess Kori bustard recruitment as well as habitat suitability in the Serengeti ecosystem to develop future conservation strategies.

Key words: *Breeding, season, habitat, sex ratio, Serengeti plains*

INTRODUCTION

Different birds exhibit a variety of breeding systems (Davies 1985) including a polygamy mating system in bustards. The most extreme and specialised example of breeding system is polygamy in birds and involve lekking where males display in congregation. Females visit such leks solely to assess a potential mate to copulate (Höglund and Alatalo 1995). Leks are described as "exploded" when males within a display aggregation are separated by considerable distance and aggregation cannot be detectable until displaying males are mapped over large areas. Exploded lekking occupies a position between classical and resource-based leks and appear to be particularly widespread among the Otididae family (Morales, Jiguet, *et al.*, 2001). The study of a species' breeding system and factors influencing breeding habitat selection is most important in considering conservation approaches for the species (Morales, Jiguet, *et al.*, 2001).

The *Kori Bustard Ardeotis kori strunthiunculus* is the largest flying bird belonging to the bustard family (Otididae). The species is indigenous to the grasslands and lightly wooded savannah of southern and eastern Africa (Lichtenberg and Hallager, 2008). The population of the species is declining over its entire range due to low reproductive rates (Lichtenberg and Hallager, 2008), reduced breeding, shrub encroachment, unregulated and illegal hunting and degradation of habitat range (Senyatso, Collar, *et al*., 2013). Currently the species is considered as near threatened (BirdLife-International, 2016).

Kori Bustard is a polygamous species (one male mate with multiple females) which tend to be gregarious outside the breeding season, (Osborne and Osborne, 2001). During the breeding season, the Kori Bustard males occur either singly or gather in loose lek-like formations and perform "balloon" displays to attract females. This behaviour is most intense in the early morning and evening (https://en.wikipedia.org/wiki/Kori_bustard).

As in other bustard species, the female Kori Bustard makes no real nest, rather a shallow scrape on the ground, which is usually near a small clump of grass allowing the nesting female to hide. Kori Bustard clutch sizes range from one to two eggs while three eggs are rare (Osborne & Osborne, 2001).

Although the Kori Bustard occurs in northern Tanzania, there is no published data on its breeding ecology in the Serengeti ecosystem. This paper, present data on Kori Bustard breeding ecology including the occurrence of courtship displays, nest site (four different areas) and habitat (grass colour and height) selection, clutch size, breeding season and male-female sex ratio in the grass plains of the Serengeti National Park (SNP). The aim of this study was to determine the timing and location of the Kori Bustard breeding activity in the Serengeti study area. We tested the hypotheses that Kori Bustard prefer short grass and green grass habitat and that the peak of the breeding season occurs during the long rainy season (March to May). In addition, a description on temporal distribution of male courtship behaviour, nest detection, and chick observations is given. It was hypothesised that the Kori Bustard courtship displays occur before the peak of breeding season and during the colder parts of the day and that the breeding season would be quite long and examined nest and chick predation as a possible cause of this long breeding season.

METHODS

Study area

The Serengeti National Park is one of the two main components of the Serengeti-Mara ecosystem (SME), located between latitudes 1° 28'-3° 17' S and longitudes 33° 50'- 35° 20' E and extending from northern Tanzania to south-western Kenya. The SME covers a total land area of approximately 25 000 km^2, of which 14 763 km^2 lies within the SNP and 8 094 km^2 in the Ngorongoro Conservation Area. The average annual rainfall varies from 600 mm in the south-east plains to 1 100 mm in the north (Pennycuick, 1975). The mean temperature ranges between 15 ^{O}C to 27 ^{O}C. The temperature is usually higher in the western parts compared with the eastern parts and may rise to more than 36 ^{O}C during the dry period. This research focused on the southern SNP, an area dominated by short grass plains and where

Kori bustards (study species) are frequently observed.

A major part of the SNP is dominated by Acacia savannah woodlands and riverine forests, particularly in the western and northern parts (Senzota, 1982). However, grasslands dominate in the southeast.

There are two major seasons in the ecosystem: a wet season extending from November to May and a dry season extending from June to October. These seasons are further subdivided into short dry (January to March) and long dry (July to September), as well as long rain (April to June) and short rain (October to December) seasons (Norton-Griffiths, Herlocker, *et al*. 1975). Although exact start and end times for dry and rain seasons vary annually, Norton-Griffiths four-season designation for our analyses was used.

Field data sampling

Data were collected over two breeding seasons between January 2014 and August 2015. During the study period a survey was done on a 1 878 random 1 km transects over the entire study area without transect overlap. Transects were surveyed from a vehicle, driving at a speed of approximately 20 km per hour. Transect surveys were conducted from 07:00-18:00 during the first week of every month for four days with a maximum of 25 transects per day and a minimum of 100 transects per month.

The variables observed included; 1) grass colour (green = 80-100% green, greenish 10-80% green, and brown = 0% green); 2) grass height (short < 10 cm, medium = 11-30 cm and tall ≥ 30 cm), which, together, defined six different habitat types; 3) season (short dry (January-March), long rainy (April-June), long dry (July-September) and short rainy (October-December) and 4) time of day (morning = 07:00-10:00, midday = 11:00-14:00 and evening = 15:00-18:00). Grass colour was categorized as green when completely green, greenish when ranging from nearly dry to yellowish, and brown when completely dry. Grass height was measured by tape measure (100 cm) followed by visual estimates of grass. Measurements were taken where Kori bustards, nests, chicks, sub-adults and courtship display were seen and estimated with the surrounding grass height when more than one Kori bustards were observed within the same transect. The study area in the southern SNP Plain was categorised into four sites (southwest SW, southeast SE, northwest NW and northeast NE) (Figure 1).

The sex of adults was determined as male when individuals were larger in body size with thick necks and/or a darkened throat (during the breeding season) and as female when individuals were smaller in body size than males and had black on the crown (Bailey and Hallager, 2003). Sub-adult individuals were differentiated from adults when they were observed to have different features from adult birds. Sub-adult males are larger resembling adult males but with a thinner neck and are larger than sub-adult females. Sub-adult females have thinner legs than adult females and a brown-black back (Osborne and Osborne, 2001). The adult male and female Kori bustards were counted during transect surveys and counts were used for determining the sex ratio in relation to the study area, seasons, sites and habitats.Courtship display (number of

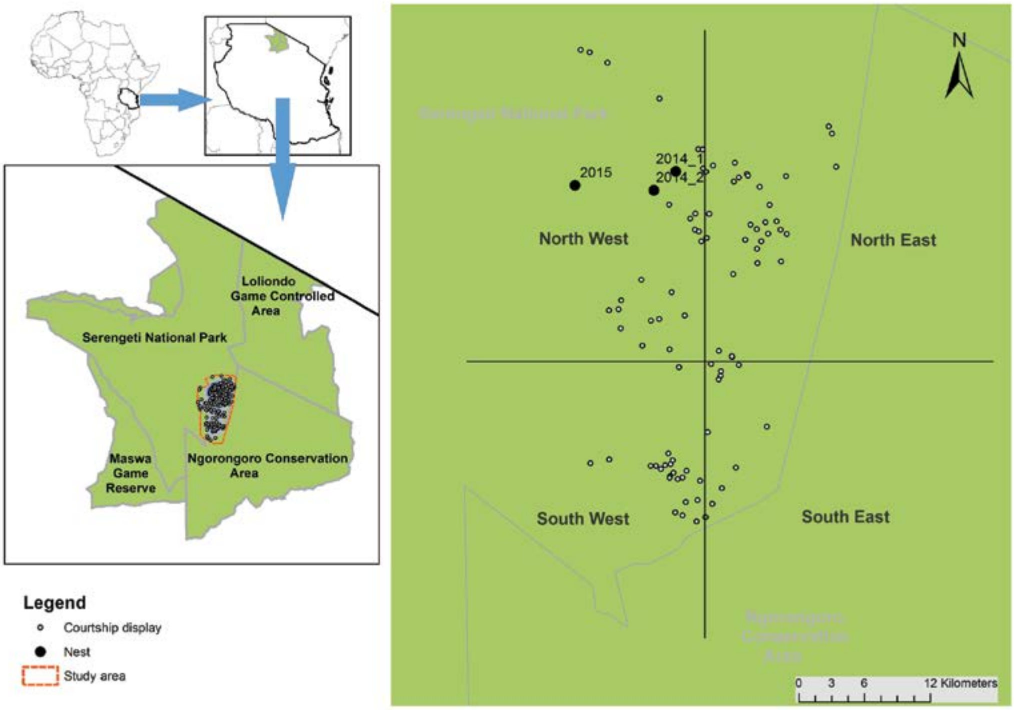


***Figure 1**: Serengeti National Park, Kori bustard study area. Open dots indicate male Kori Bustard courtship displays, while dark closed dots indicate different nests of one GPS satellite collared female in 2014 and 2015.*

displaying individuals males) was recorded when the male Kori Bustard showed a full neck and tail white feather display as described by Lichtenberg and Hallager (2008).Females hiding in the grass were treated as indication of nesting females, and the search for nests was intensified. Observed nests, chicks and sub-adults in different habitats, sites and seasons were recorded. Egg number was recorded together with egg width and length (in mm) using a Vernier calliper. The adult sex ratio was expressed as tertiary sex ratio (the ratio at sexual adulthood) and quaternary male/ female ratio in adults past the age of sexual reproduction (Mayr, 1939), as the total number of adult males divided by the sum of adult males and females observed during the fieldwork. Thus, sex ratio is expressed as a number around 0.5.

Chicks and sub-adults were photographed using a digital camera, and body size of sub-adults was estimated in relation to the size of adult birds. *Kori bustards* chicks were easily identified as their mother accompanied them. The chicks studied ranged in age from one to 24 weeks. Their age was estimated based on the 2014 international studbook for the Kori Bustard (SNZP, 2014) by comparing individual chicks with pictures in the book. In addition to random transects, nests were also located using GPS satellite collars attached to nine female Kori bustards (Mmassy, Fyumagwa, et al., 2016). GPS positioning was used to mark areas of /and nesting females. Consequently, abundance data of all variables were recorded as presence (1) or absence (0; viz. missing observations were recorded as 0) of nests, chicks or sub-adults respectively.

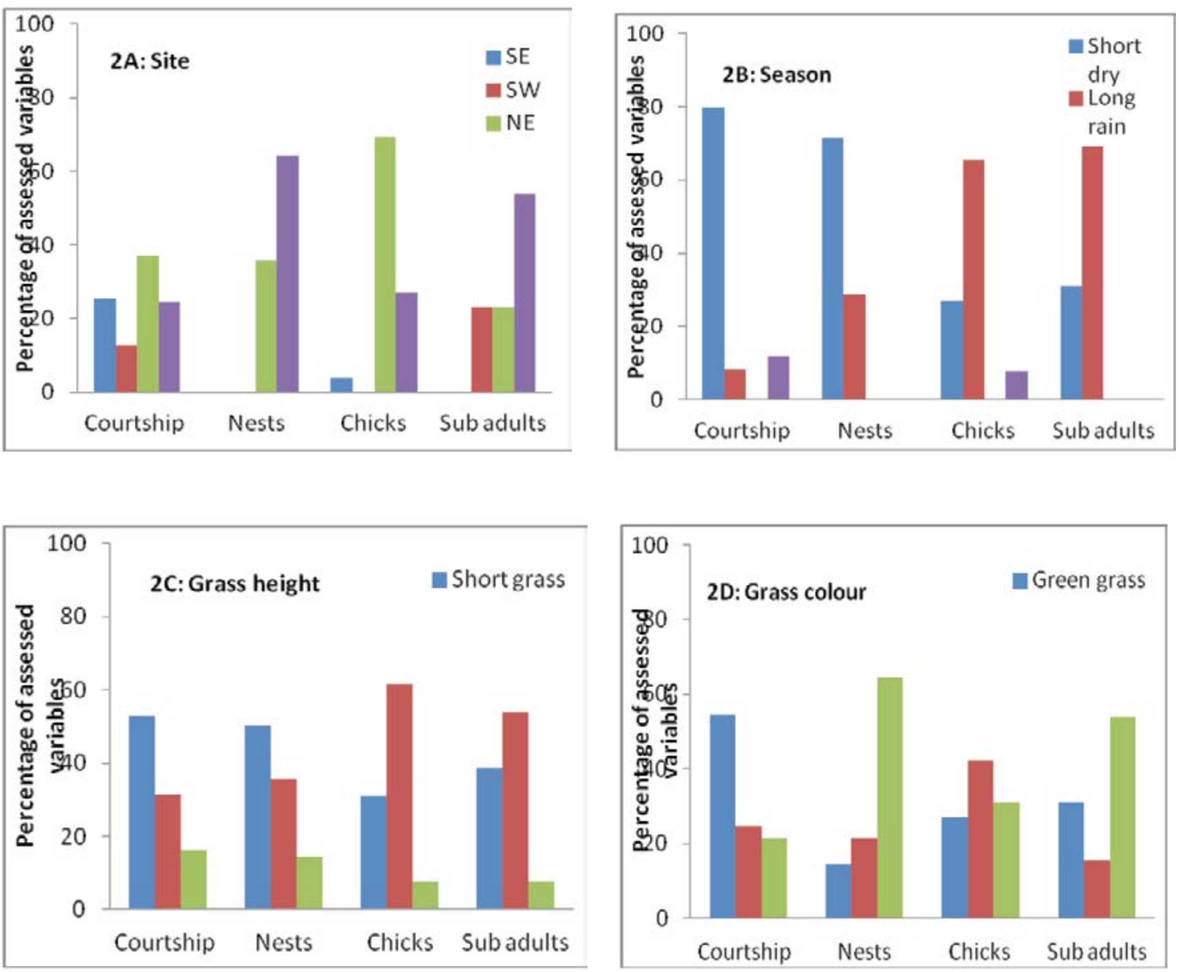
Data analysis

To examine the relation of environmental factors (site, season, grass height, grass colour, and time of day) to the frequency of courtship display, nest, chick, sub-adult, and adult sightings, first performed chi-square tests for each pair of variables was done. A logistic regression models to examine the association of all environmental variables taken together and outcomes of interest. The mean sex ratio of adult males and females under different environmental conditions was determined by adult males/ (total number of adult males + total number adult females). Fisher's exact probability test was used to determine the probability that two eggs will results into two chicks. The significance level of all statistical tests was set at alpha ($P \leq 0.05$). All tests were Bonferroni corrected.

RESULTS

Courtship behaviour

In total, 1 878 transects were conducted for nineteen months in which 1, 157 adults Kori bustards were recorded including 94 displaying individual males. The rate of courtship display differed significantly between sites ($\chi^2 = 29.29$, df = 3, $P < 0.001$). The highest rate of courtship display was observed in NE (Figure 2A). The observed courtship rate in NE was significantly higher.



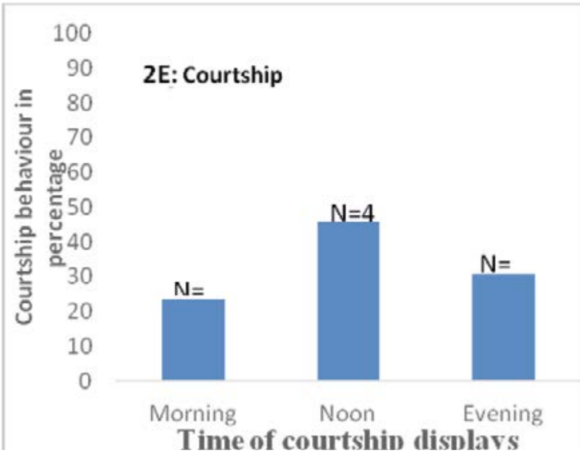


Figure 2 A - E: *Observations (percentage) of courtship displays, nests, chicks, sub-adults and time in the Serengeti grass plains in relation to site, season, habitat and grass colour.*

Than in SE (χ^2 = 43.9, df = 1, P < 0.001), as well as that of NW (χ^2 = 6.33, df = 1, P =0.012), but not in SW (NS), (χ^2 = 2.13, df = 1, P = 0.145). However the rate of courtship display differed also significantly between SE and SW (χ^2 = 25.1, df = 1, P < 0.001), as well as between SE and NW (χ^2 = 40.0, df = 1, P < 0.001), but not between SW and NW (NS), (Figure 2A). Furthermore, the rate of courtship display differed statistically significantly between seasons (χ^2 = 11.25, df = 3, P < 0.010, Figure 2B). The highest rate of courtship displays was found in the short dry season (Figure 2B) and no courtship display was found in the long dry season (Figure 2B). The difference between short dry and long rain was significant (χ^2 = 25.2, df = 1, P < 0.001), as well as between short dry and short rain (χ^2 = 5.84, df = 1, P = 0.016). No other differences were significant (NS), (Figure 2C, 2D & 2E).

A logistic regression analysis with behaviour (courtship, no courtship) as the dependent variable and site, season, time of day, grass height and grass colour as the independent variables indicated that only site was a significant contributor to the variation in courtship displays (Table 1).

Table 1: Logistic regression analyses with dependent values (horizontally) and independent values (vertically). All independent variables were used in all tests except for time of the day, which is used only for courtship display

	Courtship behaviour		**Nests**		**Chicks**		**Sub-adult**	
	Wald	***P*** (N= 655)	***Wald***	***P*** (N= 655)	***Wald***	***P*** (N= 655)	***Wald***	***P*** (N= 654)
Site	9.869	0.002	1.797	0.179	0.369	0.544	0.555	0.459
Season	0.920	0.338	0.946	0.322	3.199	0.074	0.137	0.725
Grass height	0.396	0.529	5.520	0.019	3.363	0.067	0.503	0.297
Grass colour	0.694	0.405	4.786	0.027	0.174	0.676	1.086	0.485
Time of day	1.222	0.269						
Adjusted r^2		0.056		0.209		0.053		0.031
Wald χ^2		258.2		200.3		253.4		193.6
Wald p		<0.001		<0.001		<0.001		<0.001

Sex ratio

The adult male to female sex ratio differed statistically significantly between different seasons (F =13.58, df = 3 and 655, *P* < 0.001). A Tukey post hoc test revealed that the short dry season differed significantly from the long rain season (*P* < 0.001), and long rain season differed significantly from the short rain season (*P* = 0.008). No other differences were significant (NS).

The adult male to female sex ratio differed statistically significantly between different sites (F = 6.58, df = 3, and 654, *P* < 0.001). A Tukey post hoc test revealed that SE site differed significantly from NW site (*P* < 0.001), and SE site differed significantly from NE site (*P* = 0.009), while SW site differed significantly from NW site (*P* = 0.039). No other differences were significant (NS). The adult male to female sex ratio differed statistically significantly between different grass colours (F =5.86, df = 2 and 655, *P* = 0.003). A Tukey post hoc test revealed that the green colour differed statistically from brownish colour (*P* = 0.003). No other differences were significant (NS). No differences in sex ratio were found between different grass lengths (NS).

Nests and clutch size

Totally, 14 nests with a total of 20 eggs were recorded. Among the recorded nests, five were observed in 2014 and nine in 2015. However, 36% of the nests were predated. The clutch size varied between one and two eggs. The mean clutch size was 1.4 eggs (± 0.5 SD, N = 14), while the mean egg length and width were 85.2 ± 4.2 mm and 58.7 ± 1.6 mm respectively (N = 19).

Based on data obtained from a bird with a GPS satellite collar we observed a female undertaking repeated nesting attempts during the study period. This female nested three times in different locations in the NW site during a single breeding season in March and May 2014 and again in January 2015. The nesting distance between two nests in 2014 was 2.6 km. The distance between the second nest in 2014 and the nest in 2015 was 9.3 km. The highest number of nests (64.3 % of the total observations) was found in the NW site (χ^2 = 11.70, df = 3, P = 0.008), (Figure 2A), while no nests were observed in the SW and SE sites. The observed number of nests was not statistically significant between different sites; SE and NW (χ^2 = 3.03, df = 1, P = 0.082), SW and NE (χ^2 = 1.64, df = 1, P = 0.201), SW and NW χ^2 = 4.343, df = 1, P = 0.037), NE and NW χ^2 = 3.276, df = 1, P = 0.070). Most nests were observed during the short dry season (71.4%, N = 10) of the total observations); however, a few nests were also recorded during the long rain season (28.6%, N = 4) of the total observations, Figure 2B). Though more nests were observed during short dry season there was no significant difference in observed nests between seasons (χ^2 = 2.363, df = 3, P = 0.501) and grass height (χ^2 = 0.159, df = 2, P = 0.923) was found, probably due to our low sample size (Figure 2C). Furthermore, most nests were found in the brownish grass habitat (χ^2 = 10.70, df = 2, P = 0.005, N = 9, Figure 2D).

The observed nests between green and greenish grass were statistically significant (χ^2 = 7.733, df = 1, P = 0.005). No other differences were significant (NS).A logistic regression analysis with the frequency of nests (presence and absence) as the dependent variable and site, season, grass height and grass colour as the independent variables indicated that grass colour and height of the grass were the most significant factors contributed to the variation in nest distribution (Table 1).

Chicks and sub-adults

Females with chicks were observed 25 times, among these observations each female had a single chick and only one female was observed with two chicks making a total of 26 chicks, with an average brood size of 1.0 chicks per brood. Again, 23 subadult Kori bustards were recorded, 69.2% during long rain and 30.8% during short dry (χ^2 = 19.82, df = 3, P < 0.001, Figure 2B). A Fisher's exact probability test (P = 0.004) indicated that there were significantly more two-egg nests (8/14) than two chick broods (1/26) indicating that many two-egg nests did not result in two chicks. There were significant difference in observed chicks between sites (NE, NW, SE and SW) (χ^2 = 8.73, df = 3, P = 0.033, however (69.2%, N=18) of chicks were found in NE (Figure 2A). The higher rate of observed chicks was in NE and was statistically significant between SW and NE site (χ^2 = 6.099, df = 1, P = 0.014, No other differences were significant (NS).

Table 2: Distribution of Kori Bustard sex ratio (number of males/number of males + number of females; Numbers > 0.5 indicate skewed female sex ratio while numbers < 0.5 indicate male sex ratio), in relation to site, season, habitat, grass colour and time during breeding season (N = 1 157 observations of adult Kori bustards).

Variable categories		Sex ratio ± SD	No of *Kori bustard* observations	No of transects
Site	SE	0.62± 0.46	66	317
	SW	0.51 ± 0.46	95	263
	NE	0.43 ± 0.45	294	510
	NW	0.36 ± 0.45	203	807
Season	Short dry	0.51 ± 0.46	441	781
	Long rain	0.22 ± 0.36	134	610
	Long dry	0.58 ± 0.49	6	208
	Short rain	0.43 ± 0.46	78	298
Grass height	Short	0.46 ± 0.46	323	1131
	Medium	0.41 ± 0.45	260	746
	Tall	0.49 ± 0.46	9	20
Grass colour	Green	0.51 ± 0.45	299	588
	Greenish	0.41 ± 0.45	151	413
	Brownish	0.37 ± 0.47	208	896

Majority of the 26 chicks of different ages ranging from one day to two months were recorded during the long rainy season (65.4%, N =17) followed by the short dry seasons (26.9% N = 7) and short rainy (χ^2 = 34.13, df = 3, P < 0.001, Figure 2B). The observed chicks in short dry season and long rain season was statistically significantly higher (χ^2 = 32.054, df = 1, P < 0.001), as well as between long rain season and short rain season (χ^2 = 6.265, df = 1, P = 0.012). No other differences were significant (NS). No significant difference was found between chicks and different grass height (χ^2 = 5.50, df = 2, P = 0.064 but there was significant difference between chicks and grass colour (χ^2 = 6.47, df = 2, P = 0.039) (Figure 2C & 2D).

A logistic regression analysis with presence of chicks or no chicks indicated that grass height and season were almost significant contributors to the variation in the distribution of chicks (Table 2). Finally, a logistic regression analysis with (subadult, no subadult as the dependent variable and sites, season, habitat and grass colour as the independent variables indicated that only season was a predictor for the variation in observed subadults (Table 2).

DISCUSSION

The aim of this study was to determine the timing and location of the Kori Bustard breeding activity in the Serengeti study area. We tested the hypotheses that Kori bustards prefer short grass and green grass habitat and that the peak of the breeding season occurs during the long rainy season (March to May). In addition, we describe temporal distribution of male courtship behaviour, nest detection, and chick observations. We hypothesised that the Kori bustards courtship displays occur earlier before the peak of breeding season and during the colder parts of the day and that breeding season would be quite long and examined nests and chicks predation as a possible cause of this long breeding season.

Important findings in this study is that courtship behaviour is influenced by season and site. Breeding occur almost throughout the year as chicks were observded in all seasons except long dry season. Females undergo several breeding attempts in a single season if the previous nest is predated. Sex ratio is female skewed during long dry season and males during nesting season (long rain season).

The results indicate that the courtship behaviour of the Kori Bustard in the Serengeti plain peaks during the short dry and short rainy seasons, and before the peak of nests and chicks. As birds normally have their young in the nest when food is abundant, they must lay eggs sometime earlier (Perrins 1970). Previously published data on the density of Kori bustards in the Serengeti plains indicated that during the short dry season individual Kori bustards become more abundant in the study area than in other seasons (Mmassy, Fyumagwa, et al. 2016). The appearance of a high number of individual Kori bustards during that season may reflect the onset of the breeding season. Our results corresponds with a study on Australian Bustard (*Eupodotis australis*) which found that breeding is critical during the late dry season and before the nesting period (Ziembicki 2010). We also postulated that courtship display would occur in the short grass habitat, as this would allow females to see displaying males easily. Yet, we found that courtship display occurred most frequently in habitats with short grass, although the difference was not statistically significant. This may suggest that the courtship occurs in the presence of good resources as it has been reported that when reproducing the Great Bustard select habitats with good food resources (Moreira, Morgado, *et al*., 2004) rather than habitat with less or no food resources. Similarly, studies on the Little Bustard (*Tetrax tetrax)* conducted in central Spain have found that males and females occupied areas with abundant food resources during breeding season as reproductive territories (Tarjuelo, Paula Delgado, et al. 2013, Traba, Morales, et al. 2008). However, this does not apply to all bustard species. A recent study in Spain on the Great Bustard found the short grass habitat to be important during courtship as it increased the visibility of displaying males to females (Alonso, Magaña, *et al*., 2012), although the study did not control for the grass length.

The courtship displays occurred with highest frequency during the noon hours although it was not statistically significant. This finding differs slightly from our prediction that courtship display occur only during the morning and late afternoon. However it occurred in all times of the day with different frequencies. The result, concurred with Kori Bustard observations in captivity (i.e. in zoos), where they have been found to display during noon (Gompu 2012) as well as during the morning, afternoon and evening hours (Hallager and Boylan 2004). It is however, not known if it was statistically tested and how often it was observed. These differences in the time of courtship displays between Kori bustards in captivity and natural habitats may as well be due to variations in environmental conditions such as temperature, although more research is needed to explore whether this is the case.

All over, the sex ratio tended to be female skewed, and in most case statistically significantly so. During the breeding season the sex ratio was extremely female-skewed and not male-biased as hypothesized. This may be due to the role of the male Kori Bustard during breeding and nesting seasons. Research on Little Bustards has shown that courting is the main duty of males during the breeding season (Jiguet and Bretagnolle 2001) and that male Little Bustards do not seem to participate in the parental investment beyond the provision of gametes during mating (Jiguet, Arroyo, *et al*., 2000, Moreira, Morgado, et al. 2004). Our research suggests that since male Kori Bustards do not participate in incubation or take care of the offspring, they may move to other areas. Post-mating migration has been reported in Great Bustard males in summer regions. Environmental factors such as search for feeding ground and conducive ambient temperature have been explained as the cause of post-mating migration in Little Bustard *(Alonso, Palacín, et al.*, 2009, Morales, Alonso, et al. 2000). However, more research is needed to test whether partial migration of male Kori Bustard after mating occurs in the Serengeti plains, and where do they go and how far, although there are indications that bustard density drops dramatically in the study area after the breeding season terminates (Mmassy, Fyumagwa, *et al.*, 2016).

High frequency of nests were observed in short grasses and most chicks were sighted in medium sized grasses. Results from Great Bustard studies on nest-site selection have suggested that females look for habitats with good visibility while incubating (Magaña, Alonsojuan, *et al.* 2010). Similarly, research on the breeding habitat of the Houbara Bustard (*Chlamydotis macqueenii*) in the Central Steppe of Iran indicates that the Houbara Bustard nests in short grass habitats to spot approaching predators (Zadeh, Hemami, *et al.*, 2010). What is more, research on the Asian Houbara Bustard (*Chlamydotis (undulata) macqueenii*) in Mori Xinjiang-China and on the Houbara Bustard (*Chlamydotis (undulata) jacquin*) in Central Saud Arabia have found that these species breed in habitats with significantly lower grass height (Combreau and Smith 1997, Yang, Qiao, et al. 2003). However this lower grass height was not classified as we did. The camouflage and spotting of enemies due to predation might lead Kori bustards to nests in short grass and hide chicks in the medium grass height.

The highest frequency of subadults appeared during the long rainfall season and after the peak of nests and chicks. The latter was observed to take place during the short dry, short rainy and long rainy seasons. Observations of chicks during the short dry, the short rainy as well as the long rainy seasons seems to imply that the Kori Bustard breeding season may last for almost nine months (from October to June), covering all seasons except the long dry season. We were unable to acquire enough samples to test if female Kori bustards undergo several breeding attempts within a single breeding season if the nest is predated. Although, we observed one female Kori Bustard that nest twice within a single season this is not enough to justify the case statistically. Also, since multiple nesting attempts were observed, it seems that this may happen in other Kori bustards. Using GPS satellite collars, we found evidence that one female underwent repeated nesting in a single breeding season during the first year of our study and nested again in the second year, all at different locations. Observations of few nests, chicks and subadults may indicate a predation loss of nests and chicks or it is because of few observations due to low detectability of chicks and nests because they may be hidden in the tall grass to protect themselves from being detected by predators. The nest predation in our study accounted for 36% loss of the observed nests. We found evidence of predation through GPS-monitored nests. Crushed eggs and presence of teeth marks like that of mongooses or jackals remained on egg shells. Again, research on other bustard species seems to support this finding. For example, a study in central Spain showed that up to 39% of Great Bustard clutches are lost due to egg predation (Magana 2007). Similarly research was observed in Asian Houbara Bustard in which 85% of nests were lost because of predation (Koshkin, Burnside, et al. 2016). Nest predation is the primary source of nest loss across a wide diversity of species (Martin 1993, Ricklefs 1969). In Great Bustard (*Otis tarda*) nest losses and chick mortality are largely attributed to predation and starvation (Abdulkarimi, Daneshyar, *et al*. 2010, Magana 2007). This may apply to the Kori Bustard, being a grasslands ground-nesting bird.

The mean clutch size of Kori Bustard found in this study might be small compared with the mean clutch size of other bustard species (Koshkin, Burnside, *et al*., 2016, Osborne and Osborne 1998, Rocha, Morales, *et al*., 2013). The Great bustards in Spain and Hungary has shown to have even smaller clutch size (Morales, Alonso, *et al.*, 2002, Watzke 2007). As for the number of chicks per brood, we observed an average brood size of 1.0 chicks per brood, which indicates that at least one chick can be raised by a single female and raising of two chicks can be rare.

It was concluded that the peak frequency of courtship displays occurs during the early stages of the breeding season that means short dry period. The Kori Bustard nests more in short and medium grass habitats and it can undergo several breeding attempts within a single breeding season due to nest predation. Few observations of nests, chicks and subadults may support the prediction that the nest predation may be high. Other reasons which may contribute to nesting failure and which need to be studied, includes predation of nesting females, climate change, fire management etc. Fire may be an additional factor of nest losses in Kori bustards as ground nester due to fire regime management in the ecosystem to stimulate biodiversity and to increase biomass. Male-skewed sex ratio after the mating period may indicate a post-breeding movement of males. Finally, we conclude that the breeding season of Kori bustards in the Serengeti plain is relatively long because of observed chicks for several months, with the exception of the long dry season. A study of Kori Bustard breeding ecology is of great importance as it is a near threatened species, listed in appendix II of CITES. It is therefore crucial to understand its breeding ecology for further action towards conservation of the species. We recommend that management authorities conduct a recruitment assessment of Kori bustards in the Serengeti ecosystem to develop future strategies for the conservation of the species. This should include studies on habitat preferences by the species inside and outside the protected areas, the buffer zones, and seasonal migration grounds.

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WHEN MONITORING MATTERS: 10 YEARS (2007-2016) OF UDZUNGWA ECOLOGICAL MONITORING CENTRE

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ABSTRACT

In times of unprecedented biodiversity crisis, field stations annexed to protected areas, often in biodiversity hotspots, are of increasing importance to boost ecological research and monitoring, and standardize monitoring protocols. In this context, the Udzungwa mountains in south-central Tanzania represents a model site. It is an ancient mountain range partially covered in Afromontane forest holding outstanding biological diversity and endemism. A field station annexed to the Udzungwa Mountains National Park, the Udzungwa Ecological Monitoring Centre (UEMC),was established in 2006 as a collaboration between Tanzania National Parks and Italy's MUSE – Science Museum. UEMC mission is to increase our understanding of the biological importance of the Udzungwa mountains by promoting and facilitating research and monitoring of biological diversity. We review achievements and perspectives of UEMC at its first decade of operations. Main achievements include: hosting nearly 600 researchers, including23 Ph.D. students;more than 120 papers in ISI journals have been published, 59% of which by researchers facilitated by UEMC; boosting ecological monitoring, by directly implementing programmes such as the Primate Monitoring Programme and TEAM Network Programme; providing technical advisory and capacity building to the national park (50 ecologists and 40 rangers trained), hosting summer schools and field training classes for international and local students; facilitating a number of external projects and institutions working in the area; hosting a community education programme (more than 2,000 pupils involved each year in environmental education), and boosting community conservation including the establishment with various partners of a Visitor Information Centre for the park.UEMC has succeeded in placing the Udzungwa mountains on the map of globally important areas for biodiversity research and monitoring, and become a candidate model site for standardization of monitoring protocols in forest habitat at national and regional levels.

Key words: *Biodiversity monitoring, primates, Tanzania, tropical forest, Udzungwa.*

INTRODUCTION

The Udzungwa Ecological Monitoring Centre (UEMC) is a field station of the Udzungwa Mountains National Park (UMNP), Tanzania, established by Italy's MUSE – Science Museum in 2006 in partnership with Tanzanian National Parks (TANAPA). Beyond providing accommodation and research facilities to local and visiting scientists and students, UEMC aims to provide technical advisory to the National Park and, more generally, to facilitate research, conservation planning and community outreach programmes in the area. Among the strategic activities, UEMC contributes to the implementation of biodiversity monitoring programmes, the organization of training courses for rangers, park ecologists and university students, the promotion of school education programmes for scholars, as well as networking with other biological field stations in the tropics.

Located in south-central Tanzania, the Udzungwa Mountains (hereafter also called 'Udzungwas') occupy an area of approximately 19,000 km^2 (Platts *et al*. 2011), comprising the largest remaining forests blocks in the Eastern Arc Mountains, a renowned region ranging from southern Kenya to Tanzania within the *Eastern Afromontane Biodiversity Hotspot* (Fig. 1). Covering an altitudinal gradient of 300 m in the Kilombero valley to 2,576 m at Luhomero peak, the Udzungwas include tropical lowland and montane rainforest, as well as *miombo* woodland, dense dry forest, and grassland. This region holds outstanding levels of biological diversity and endemism comprising more than 400 bird species, over 120 mammals and 2,500 species of plants. Owing to a combination of natural (i.e., geology, climate) and human-induced factors (i.e., subsistence and commercial logging, pole cutting agriculture, bushfires), the habitats in Udzungwa are highly fragmented, making a mosaic of intact and modified closed-canopy forests interspersed with drier habitats, settlements and agricultural areas. In particular, the conversion of surrounding lands in the Kilombero valley into intensive agriculture for sugar cane and rice, and the associated infrastructural and human population increases, pose the highest threats to biodiversity in the Udzungwa landscape (Rovero *et al*., 2012).

By the early 2000s, the outstanding biological value of the Udzungwas had triggered considerable international research attention. This matched the mission of TANAPA for the conservation of the outstanding natural heritage in the country, and its mandate of realizing an ecological monitoring centre in each park to effectively monitor biodiversity. Concomitantly, MUSE - Science Museum (a world class museum of natural science in Italy) had just started a research programme within the Udzungwa Mountains National Park. MUSE merged the needs for facilitating the increased research presence in the area and realizing an ecological monitoring centre by proposing the establishment of a field station. In 2006, MUSE entered into agreement with TANAPA. This agreement was instrumental to fund and establish the core buildings first and the hostel subsequently. MUSE has run and coordinated UEMC for the first 10 years in partnership with TANAPA.

The mission of UEMC is to increase the understanding of the biological importance of the Udzungwa Mountains by promoting and facilitating research and monitoring of use of the long-term data collected within this area for developing more effective conservation management and community education plans for the preservation of the Udzungwas, as well as the adjacent Forest and Nature Reserves.

This paper describes ten years of UEMC activities towards achieving UEMC mission and it ends by outlining the perspectives. For a more detailed account, the reader is referred to Rovero and Barelli (2017).

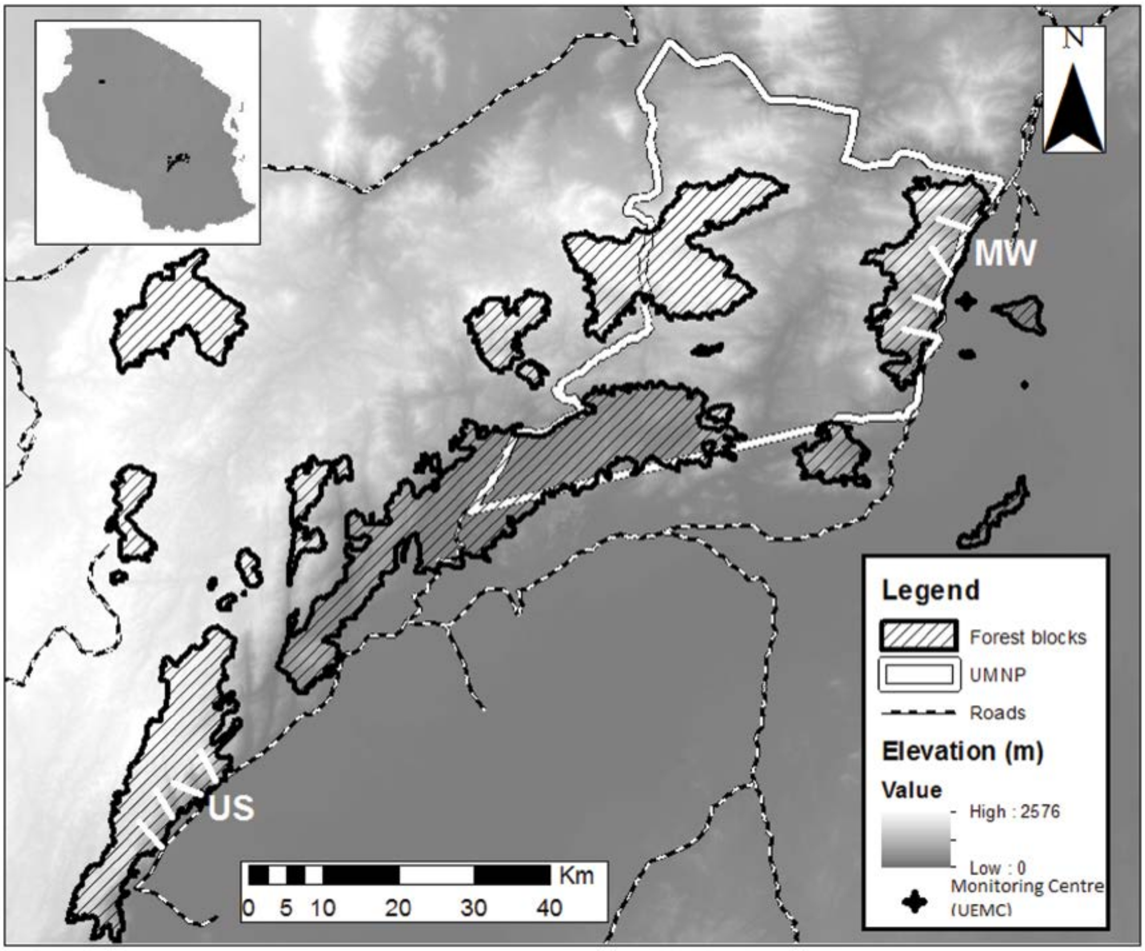

Figure 1: *Map of the Udzungwa Mountains. The areais a mosaic of forest blocks in the Eastern Arc Mountains interspersed with drier and settled or farmed areas, with most of the natural habitat protected under different reserve categories. Mwanihana (MW) is the forest within the Udzungwa Mountains National Park, which protects 1,990 km^2 in the north-eastern portion of the range, whileUzungwa Scarp Nature Reserve (US) is a former Forest Reserve recently upgraded to Nature Reserve. The Udzungwa Ecological Monitoring Centre (UEMC) is indicated with a dark star at the eastern edge of the Park border.*

ACHIEVEMENTS

UEMC management, resources and facilities

UEMC was inaugurated on the 10th of November 2006 and it is located within TANAPA plot near the park Headquarters in Mang'ula, in the Kilombero District of the Morogoro region. The structure was donated by MUSE to TANAPA and it has been managed by MUSE for the 10 years following a formal agreement between the two institutions. MUSE-employed staff, including a coordinator, have attended the daily management routines, while a management committee - formed by representatives of both MUSE and the park - has ensured smooth cooperation and decision making on any relevant administrative matters. Since 2006, UEMC staff has increased in number of employees from 8 to 22 people. UEMC has concomitantly grown in financial terms as a direct consequence of the increased volume of activities needing more personnel, vehicles and other assets. Such increase has been approximately 500%, from a budget of around 12,000 € in 2007 to around 60,000 € in 2016. While the institutional funds from MUSE have covered the bulk of funding in the first years, during the ten years of activity UEMC was able to raise more than 30% of the total income from accommodation fees (Rovero & Barelli, 2017, for more details).

In 2006, the facilities included four main buildings: an office with research facilities (Internet, computers, printers, maps and the like), a large (150-m^2) seminar room that can accommodate over 50 people, and three more buildings as researchers' houses. Each house has two self-contained double rooms, and shared kitchen corner and living room. In February 2010 two more buildings were built to enhance students' training capacity: a large dormitory block with four rooms that can host up to 24 students, and a dining hall with annexed kitchen and stores.

Over the ten years of activity, UEMC hosted national and internationalresearchers and students that lodged for short- to long-term periods. The overall number of visitors reached over 1,200 people with the vast majority being researchers and students, and the remaining share the other categories (eco-tourists, TANAPA and Government officials, secondary school students; Fig. 2).Most visitors (over 60%) came from abroad, indicating how UEMC has become a reference place, especially at international level. Of all visitors, 10% were researchers and students that stayed at UEMC for one month or more, while 39% were people lodging for less than a month.

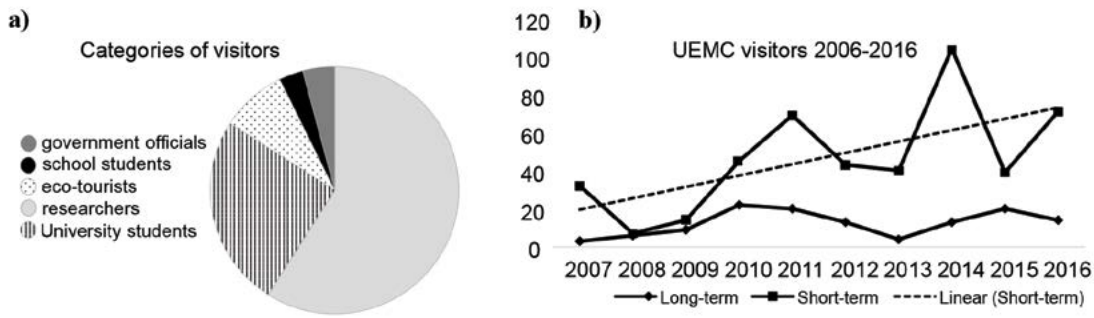

Figure 2: *Percentage of the overall UEMC visitors in the decade, classified by categories (a), and numbers of visitors distinguished by long- (more than one month) and short-term (less than one month)visits (b) across the ten years.*

Facilitating research

By facilitating individual researchers and agencies working in the area, UEMC has been instrumental to determine a sharp and relatively rapid expansion of the volume of research and conservation efforts in Udzungwas. The studies conducted by the researchers hosted at UEMC spanned a vast range of topics, from taxonomic assessments of flora and fauna (including invertebrates and vertebrates) to investigations of the ecology at population, species, community and ecosystem levels. In addition, a number of studies were primarily aimed at addressing conservation issues, for example studies on wildlife connectivity and human disturbance across a range of forests.

Asa simple way to quantify the outcome of such efforts,we scored the number of publications that have appeared in the scientific literature over the decade using dedicated search engines (Web of Science) to select publications where 'Udzungwa' appears in the title, abstract, or it is included in publications of global scope. Given the time gap between data collection and publication (which can span years, especially for taxonomic research), it is predictable that a number of publications will come out in following years. Thus, the count shown here is barely a *minimum* of the overall peer-reviewed publications, which scores 124 papers over a decade. Interestingly, 59% of such studies have been facilitated by UEMC, through either accommodating researchers or providing logistic facilitation (more detailsin Rovero & Barelli, 2017).

Boosting ecological monitoring
Primate Monitoring Programme

With 13 species, including range-restricted and endemic ones, the Udzungwas are an outstanding hotspot in Africa for primate conservation, and recently it has been also appointed as *the* top-ranking site in Tanzania for presence of globally rare, red-listed and range-restricted species and subspecies (Davenport *et al.* 2014). The Primate Monitoring Programme has been in place for nearly two decades now, representing the longest-term one, and yielding among the most important data-sets on any biological component of the Udzungwa forests. Among the diurnal primates occurring in Udzungwas, five species have been regularly monitored, including the endangered and endemic Udzungwa red colobus monkey (*Procolobus gordonorum*), the Peters' Angola colobus (*Colobus angolensis*), the Tanzania Sykes' monkey (*Cercopithecus mitis monoides*), the endangered and endemic Sanjemangabey (*Cercocebus sanjei*) and the yellow baboon (*Papio cynocephalus*).

Line transect counts are the most common method to monitor primate abundance: observers slowly walk the trail and record all sightings of primate social groups with their position along the trail, as well as the number of individuals and any other useful information (Araldi *et al.* 2014; Rovero *et al*. 2006; Barelli *et al*. 2015). The transect-based protocol for monitoring diurnal primates was placed in Mwanihana forest, one of the largest blocks and easily accessible from the National Park. Four trails of 4 km in length were identified as 'line transects' and regularly maintained and walked. Due to a relatively long phase of fine-tuning the programme, it was only from 2002 that data collection became standardized. Moreover, from 2004, the programme was extended to another critical forest: Uzungwa Scarp (now a Nature Reserve; USNR), 150 km to the southwest. By the end of 2016, an impressive sampling effort had been realized: 972 repetitions of the four transects in Mwanihana, and 401 of the three transects in USNR, which translates into over 5,200 km of transects surveyed overall (Rovero & Barelli 2017).

In brief, although considered a raw index of primate abundance, through the metric of the so called 'encounter rate', it is possible to identify the number of primate groups counted per km of transect traversed, and quantify the variation of population abundance over time (Fig. 3). Specifically, despite a key contrast in population abundance between the two forests, the results clearly show how the relative abundance is much lower in USNR than in the Park (i.e. Mwanihana forest), with the only exception of the Sykes's monkey, an opportunistic species that seemingly thrives in disturbed habitat with regenerating vegetation (Fig. 3b; Rovero et al. 2006). Moreover, and most alarmingly, while the relative abundance for these species in Mwanihana appears slightly declining, in USNR the trend is clearly negative, especially for the two colobines (Rovero *et al.* 2012). Despite two potentially confounding factors (i.e., involvement of different field technicians over the years and the sampling across different seasons), statistical analyses have shown that such trends are 'real'(Rovero *et al*. 2015). This is important because it indicates that even a simple routine data collection can yield robust results provided that the protocol is standardized and observers are well trained.

TEAM Network: standardized biodiversity monitoring in the global tropics

A second important monitoring programme is carried out through the participation of UEMC in a pantropical network of field stations since 2009. The stations coordinate the implementation of standardized monitoring protocols so that comparable data across the tropics can be available for local, regional and global studies. The *Tropical Ecology, Assessment and Monitoring* (TEAM) network has been set up by Conservation International. Currently, it includes 17 stations in the tropics across three continents. UEMC was the first 'node' of this network in Africa. By collecting and making an enormous amount of open access data available in near-real time, TEAM aims to become an Early Warning System for life on planet earth (see www.teamnetwork.org for more information).

The standardized monitoring protocols target arboreal vegetation, climate and ground-dwelling mammals and birds. The latter protocol is implemented through the use of 'camera traps' (automatic cameras that take images of passing animals), which has progressively become a key method in the Udzungwas, by providing complementary data. TEAM's 'terrestrial vertebrate' protocol consists of a grid of 60 locations in Mwanihana forest (one every 2 km^2), sampled every year since 2009, with camera traps set for 30 days.

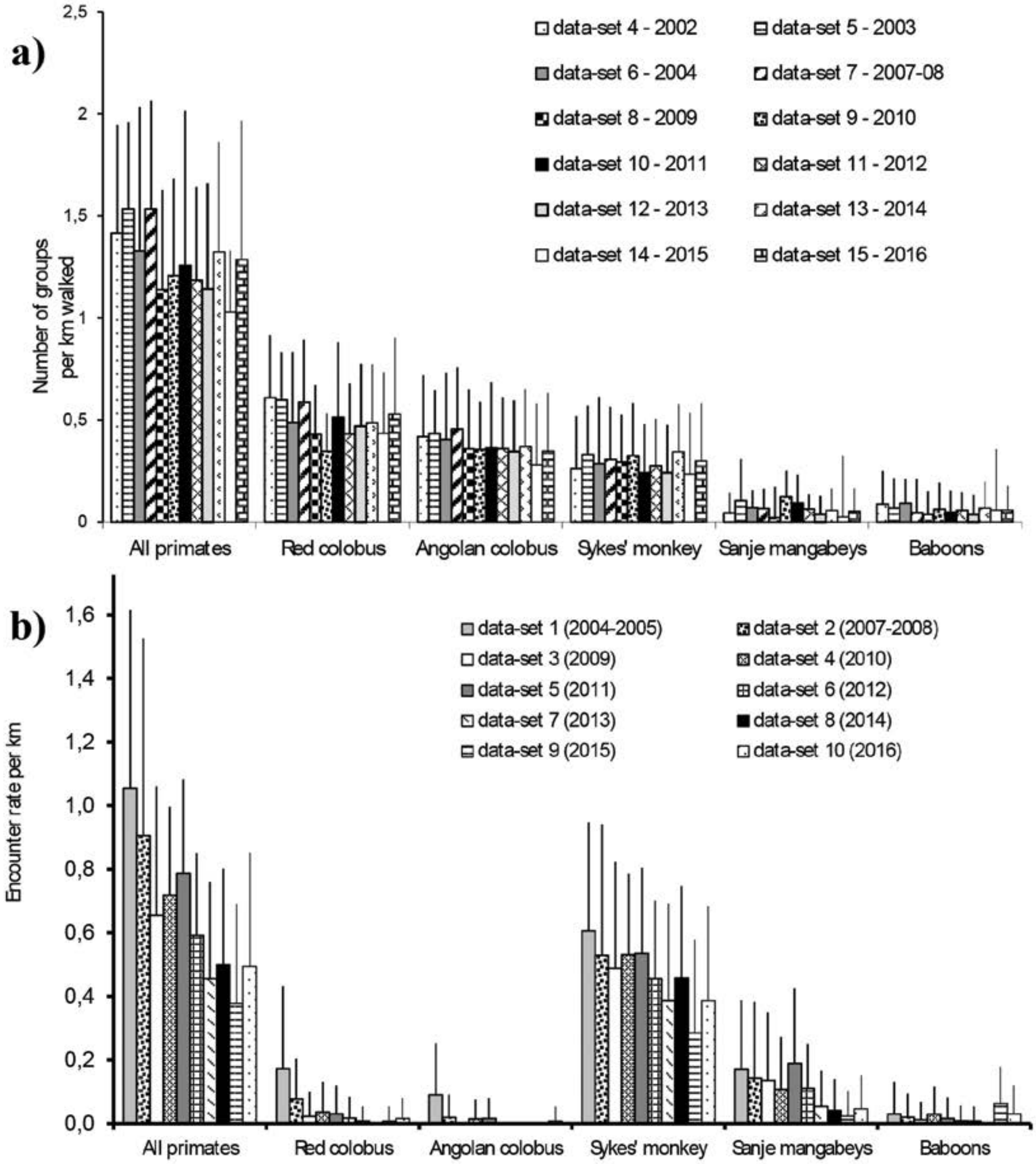

Figure 3: *Encounter rates (i.e. number of primate groups counted per km of transects walked) of 5 different primate speciesresiding in two Udzungwas' forests: Mwanihana (a) within the National Park border, and Uzungwa Scarp Nature Reserve (b) to the southwest. Each bar indicates the different year-period for which data have been collected across the ten years of sampling. Mean annual encounter rates indicate a decline in primate relative abundance in Uzungwa Scarp relative to Mwanihana, which is particularly severe for the two colobus monkeys.*

Over the eight years, a remarkable dataset of approximately 150,000 camera trap images (on average 18,600 per year) has been accumulated, with around 30 species of mammals photographed. Besides building a species inventory, such data allowed to study population abundance and changes in both populations and the whole community over space and time. These statistically robust approaches use a metric – called *occupancy* - that estimates the probability of presence of each species across a forest (see Rovero *et al*. 2014a, for methodological details). For example, the probability of presence of the common forest antelope Harvey's duiker (*Cephalophus harveyi*), also known as *funo* in Swahili, was found to increase with proximity to the edge of the forest, likely as a response to more optimal habitat towards the forest edges. Its map of predicted occupancy therefore indicates greater presence in the outer zones than in the interior forest (Fig. 4a). As another example, data derived from all species are relevant to infer temporal changes in the status of the entire mammal community, in terms of both species richness and population abundances. For example, the *Wildlife Picture Index* (WPI; see Beaudrot et al. 2016 for an example of application),sensitive to both species richness (a species that goes extinct or are new colonizers) and their abundance at each particular year,specifically quantifies temporal changes of the community status (Fig. 4b).

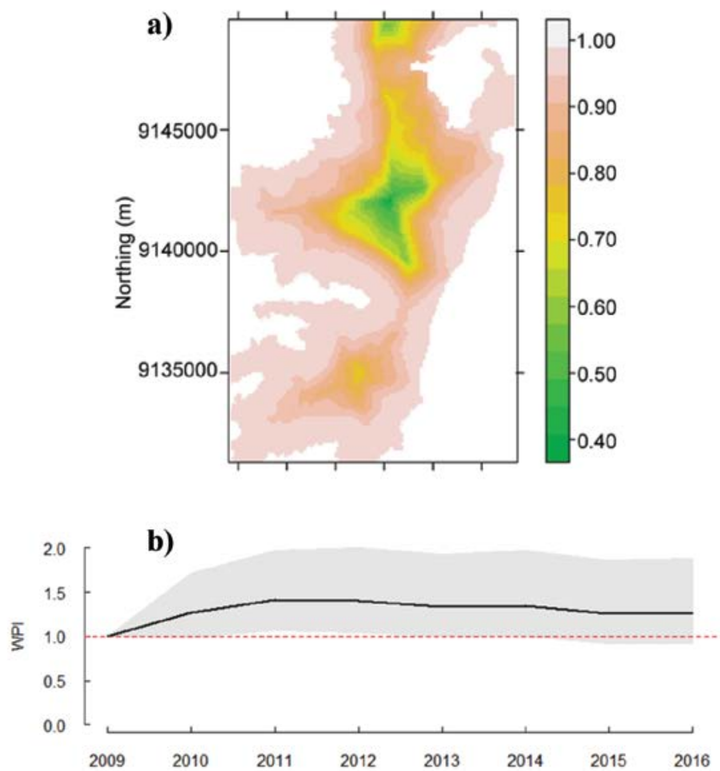

Figure 4: *Examples of analyses based on data from camera traps collected through the TEAM Network programme (see text for details).*

The map (a) shows the predicted 'occupancy' (probability of presence) of the common forest antelope Harvey's duiker. Abundance estimates are originally represented with coloured scales (reproduced from Rovero et al. 2014a), and here range from pale grey (high abundance) to dark grey (low abundance), revealing higher occupancy near forest edges. The graph (b) reports the trend of the Wildlife Picture Index (WPI, see text for details) for the community of ground-dwelling mammals camera trapped during 2009-2016 in Mwanihana forest.

A fundamental value of TEAM's programme is the availability of standardized data from several sites across the tropics, allowing for unprecedented regional and global-level analyses, to which the Udzungwas contributed. For example, by 2017, the camera trapping protocol has accumulated over 3.4 *million* images from across the global tropics. This massive date set has brought to infer about: assessments and comparisons on temporal changes; community size and composition; effects of climate changes; and, by using the data from vegetation plots, relationships and interactions between terrestrial vertebrates and forest dynamics (e.g., Ahumada *et al*. 2011; Beaudrot *et al*. 2016).

Conservation outcomes of research and focal conservation projects

A large portion of research facilitated by UEMC fell within the realms of applied ecology and biodiversity science, and as such it carried conservation relevance, with some studies that were primarily aimed at addressing conservation issues. For example, by revealing the dramatic decline of primates in Uzungwa Scarp, the Primate Monitoring Programme has been instrumental to lobbying for increasing protection of this important forest. In conjunction with various other efforts that revealed the extraordinary biodiversity of this forest, this eventually resulted in the upgrading by the Government of the protection status of this forest from Forest Reserve to Nature Reserve. Thus, the Tanzania Forest Service has allocated more staff to this Reserve and gathered funds for the necessary infrastructure and equipment. A collaboration between MUSE and the Whitley Wildlife Conservation Fund, with local facilitation from the Southern Tanzania Elephant Program, has initiated a project to build the capacity of Tanzania Forest Service's staff and support law enforcement by rangers and community scouts. This project represents an emblematic example of how applied research and long-term monitoring can trigger conservation action.

As conservation issues became to be identified at the landscape level, a number of focal conservation assessments have also been conducted. Among these, studies on connectivity stand out for importance by being critical in a highly fragmented landscape such as the Udzungwas. These studies identified and assessed the connectivity potential both within the Udzungwa (the so-called 'Mngeta corridor' linking Uzungwa Scarp and Kilombero Nature Reserves) and between Udzungwas and adjacent landscapes (i.e. Mikumi/Ruaha to the North and Northwest and Selous to the east). Such work is fundamental for 'landscape species' such as the elephants. Among the successes already achieved: the on-going gazettement of the 'Mnegta corridor' as a new Forest Reserve by the Tanzania Government, and the inclusion of the proposed 'Mwanihana-Magombera corridor', as case study of priority in the Government-led process of making regulations and establishing wildlife corridors across the country (Rovero &Jones 2012).

Technical advisory and training to TANAPA staff

As the ecological monitoring centre of UMNP, UEMC worked closely with the park's Ecology Department through sharing data from relevant monitoring efforts, such as the Primate Monitoring Programme, assisting with planning and implementing park-driven monitoring efforts, providing routine advisory on technical issues pertinent to ecological monitoring and training UMNP staff. Important monitoring efforts by the park, for which UEMC contributed,include a study on the use of dung beetles as indicators of human disturbance through firewood collection. The study, conducted in 2008 in collaboration with the University of Dar es Salaam,revealed that dung beetles' species diversity declined in areas of the forest more intensively utilized by humans, suggesting a possible negative impact of firewood collection on biodiversity. Suchpractice wasformally authorized by the park -local villagers could entered the lower portion of the forest once or twice a week to collect dead wood - but completely banned soon after the study, from July 2010.A second important effort has been the establishment of a network of routes or 'transects' of 4 to 6 km in length at five different remote ranger posts across the park in 2008. Field technicians with rangers monitored large mammals through counting direct sightings of animals, dungs, tracks and other signs. While the programme overall ran discontinuously, mainly due to shortage of funding and staff availability, it remains a valuable example of how parks can conduct monitoring with potentially limited resources, by allocating a small number of rangers and field technicians that use simple routine for collecting data.

UEMC advisory to UMNP included training on the toolkit for ecological monitoring, with a long-term view of contributing to enhance and standardize efforts to monitor biodiversity in forest parks across the country. In this regard, the above mentioned ranger-based monitoring, along with the Primate Monitoring Programme and the camera trapping monitoring by TEAM, have been instrumental to showcase protocols. Thus, aminimum of 40 rangers have benefitted from training on GPS and general biodiversity data collection over the years along with park ecologists. In addition, higher-level training was dedicated to park ecologists and assistant ecologists scaling up from the Udzungwa to other National Parks. Thus, 26 ecologists from TANAPA parks across the country altogether attended the international summer schools on GIS and field tools for assessing biodiversity run during 2011-2016. Lastly, UEMC organized two main training workshops that were dedicated to TANAPA staff (Rovero et al. 2014b): the first in 2013 on standardized methods for monitoring primates and terrestrial mammals with emphasis on transect methods, and the second in 2016 on the use of camera trapping for monitoring mammals. These workshops were attended by 20 people, representing most of the ecologists and park ecologists of all National Parks in the country.

Summer schools and study abroad programme

The 2009 inauguration of the hostel block annexed to UEMC opened the way to host and organize training programmes for students. A major one has been the international summer school organized by MUSE in partnership with the University of Trento (Italy) and, for the later editions, the University of Copenhagen - Natural History Museum of Denmark. Starting in July 2011, the international summer school entitled "Tropical rainforest biodiversity: field and GIS tools for assessing, monitoring and mapping" reached its fifth edition in 2016. Through a combination of field trips in the rainforest, and lessons and exercises on a PC, the summer school aimed to provide field and GIS experience for assessing forest biodiversity, especially rainforest mammals, integrating state-of-the-art field techniques to assess key indicator species with GIS tools to map and model species distribution. During the five editions held, 70 international students enrolled in Masters programmes from a range of countries participated, joined by staff from TANAPA and a number of students from Tanzanian Universities and conservation agencies. UEMC also offered the option of arranging independent courses and summer camps at any institution, by providing logistic support and lodging facilities. For example, every year since 2010, Pennsylvania State University has organized an integrated research-education abroad programme for a class of B.Sc. students in the general field of landscape planning and park-community interactions.

Environmental education and community-based conservation

Environmental education activities conducted by UEMC begun at its establishment, as by then MUSE had been piloting them for a few years through community conservation initiatives around the Uzungwa Scarp area. From 2010, an Italian non-profit association *Mazingira* (http://www.mazingira.net)took over the education activitiesand by 2012, the programme had expanded to 13 primary and five secondary schools for a total of 31 classes involved and nearly 2,500students every year. Topics such as environmental-friendly sources of energy, agro-forestry and soil conservation, biodiversity and eco-tourismhave beenembraced. Amid the educational activities conducted by *Mazingira* ('environment' in Swahili),this association has commenced programmes to help local communities in establishing tree nurseries, agro-forestry, and adopting energy efficient technologies (e.g. to decrease the consumption of firewood from the forest). Mazingira has also begun to explore the potential of eco-tourism in the area by organizing trips to Udzungwa from Italy.

In this context, MUSE and Mazingira have also helped in realizing the new Visitor Information Centre (VIC)at the National Park entrance, which has been inaugurated in March 2018. Given the peculiarities of the forest habitat and the complexity of the broader ecosystem, a visitor information centre is especially critical for the Udzungwa Mountains National Park.

UEMC promotion and communication activities

Since2007, the website (www. udzungwacentre.org) was activated as the virtual 'door' to use the field station, learn about its activities and get a wealth of information on the area.Information housed here includes checklists to past and on-going research with a page where reports and other publications can be downloaded. Promotion of UEMC has also been made by MUSE scientists and partners through workshops, scientific and general public conferences, as well as at training courses. In 2013, with the opening of MUSE - a leading European museum with 12,000 m^2 of exhibitions featuring local and global nature - the Udzungwa Mountains were given a prominent space in the museum exhibitions: a 600 m^2 greenhouse reproducing the Udzungwa rainforest. This represents a geographically-focused approach to highlight global conservation themes to the public, and how rainforests are emblematic of the current environmental crisis. By the summer of 2017, MUSE has been visited by more than 2.5 million people since its opening, and we believe this too helped a great deal promoting the Udzungwas and UEMC to Italians and Europeans visiting the museum. An important work to spread knowledge on Udzungwa is the book jointly published in 2015 between MUSE and the Natural History Museum of Denmark (Sharff *et al.* 2015). Beautifully illustrated, the book was contributed by most of the senior biologists that worked in Udzungwa over the last decades, collating stories of discoveries, and providing an overview on the natural history, biogeography, biological importance and conservation needs of the area.

PERSPECTIVES AND CONCLUSIONS

The current period of UEMC management, covering 2017-2021, is based on an agreement which introduced two major changes. The first is that TANAPA now manages UEMC in closer collaboration with MUSE in terms of the core functioning, such as accommodating researchers; the second is that the Natural History Museum of Denmark (NHMD) entered into the partnership by joining MUSE to provide continued funding and involvement in the area with biodiversity research projects. Hence, the alliance MUSE-NHMD has established a fund that includes both a direct contribution to TANAPA for the key functioning of UEMC, and support to running core scientific projects.

Besides management procedures, the new phase aims to:

(1) consolidate the long-term biodiversity inventorying and ecological monitoring with priority to the Primate Monitoring Programme, the TEAM Network programme and the invertebrate assessment and monitoring towards a timely and efficient use of data by the park for management decisions;

(2) continue providing technical training to TANAPA staff and other professionals from protected areas and conservation agencies for the use of standardized monitoring tools;

(3) consolidate the facilitation by UEMC of community education and community-based conservation initiatives. This latter objective includes the development of eco-tourism activities that can be

beneficial to both the park and local communities.

Along with the continuation of the long-term ecological monitoring and technical advisory to park staff, UEMC aims to continue and boost the hosting and facilitation of field-based training of students, such as summer schools and studying abroad visits. Through the international network built over the years, UEMC has now greater potential and attraction by Universities and other international programmes. Indeed, the decade of experience in conducting and facilitating biodiversity projects provides a wealth of options for making the Udzungwas a fascinating 'laboratory' of tropical forests where students can apply first-hand the diversified range of tools used to study biodiversity. Towards this goal, MUSE-NHMD plan tosupport TANAPA constructing an additional building as laboratory for all type of research that need screening, preparation, identification and storing of samples collected in the field. We believe such structure would address a significant gap in the current facilities and make UEMC attractive to a broader range of research projects.

Besides this additional infrastructural development, we ultimately hope UEMC will continue to serve for its primary and fundamental functions it was realized for: host researchers, facilitate research in the Udzungwas, support the capacity of the park and the other reserves in the area by monitoring their exceptional biological treasure, and use this knowledge to fine tune management.

In a context of ever increasing anthropogenic pressure on the forests, with rapidly escalating conflicts in land use between conservation and intensive agriculture at their surroundings, we must not overlook the importance of monitoring and protecting them. For it is precisely the very existence of these forests that provides the natural assets (water, hydropower, soil fertility, rainfall, etc.) on which thousands of people's livelihoods depend on.

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USING HOTSPOT ANALYSIS TO INVESTIGATE SEASONAL AND SEX-BASED DIFFERENCES IN THE DISTRIBUTION OF ELEPHANTS (LOXODONTA AFRICANA) IN RUAHA NATIONAL PARK, TANZANIA

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ABSTRACT

Southern Tanzania Elephant Program (STEP) has an ongoing elephant monitoring program in Ruaha National Park to collect long-term data on elephant ecology, behaviour, and demography. One key aim of the program is to understand seasonal patterns in elephant use of the ecosystem. Since February 2015, more than 100 vehicle transects (covering >10,000 km) to collect elephant sightings and dung density data along Ruaha's major rivers and across different habitats were conducted. Using Getis-Ord hotspot analysis to identify significant spatial clusters of elephant dung and elephant sightings along the transect network it was observed that the Ruaha basin and the miombo-dominated area of the plateau were used year-round by elephants. The location of elephant hotspots varied between seasons and years and were potentially related to water and forage availability as well as social and risk factors. Evidence of both spatial overlap and segregation between bulls and cow-calf groups were found.

***Key words**: Elephants, Ruaha National Park, distribution, seasonality, sexual segregation*

INTRODUCTION

Across their range, African savannah elephants (*Loxodonta africana*) show distinct seasonal differences in their ranging patterns (Shannon *et al*., 2006; Young *et al*., 2009), diet (Barnes, 1982 a and b) and behaviour (Barnes, 1982 a and b; Wittemyer *et al*., 2007). Elephant ranging behaviour is primarily driven by seasonal differences in the distribution of water and food resources in relation to periods of low and high rainfall (Wittemyer *et al*., 2007; Ochieng 2015; Birkett *et al*., 2012; Legget, 2006), but is also influenced by social and reproductive opportunities (Barnes 1982 a and b; Stokke & du Toit, 2002), risk factors (Graham *et al*., 2009), and energetic constraints (Shannon *et al*., 2006). Elephants also display sexual segregation due to differences in forage and water requirements, indirect competition, and predation risk (Shannon *et al*., 2006; Stokke & du Toit., 2002). For conservation managers, a detailed understanding of elephant distribution and the influence of season and sex on elephant ranging behaviour can help to identify key elephant areas and resources to prioritize for conservation and protection efforts.

Ruaha National Park is part of the larger Ruaha-Rungwa ecosystem (43,000 km^2) and is home to one of East Africa's largest elephant populations. In 2006, the ecosystem held 34,664 (±4178) elephants (Mduma *et al*., 2010), but commercial ivory poaching significantly reduced this population to an estimated 15,836 (±4,759) elephants in 2015 (TAWIRI, 2016). In 2015, the elephant population in Ruaha National Park was estimated at 6,573 (±3,313) (TAWIRI, 2016).

Aerial censuses conducted every three to four years by the Tanzania Wildlife Research Institute (TAWIRI) provide a snapshot of elephant distribution in the ecosystem during the dry season. These censuses reveal a band of elephant occurrence stretching from the northeast corner of the Park (Lunda) to the southwest corner (Magangwe), with generally higher elephant densities in the Greater Ruaha River than on the plateau (TAWIRI 2013, 2016). However, as population censuses are not conducted in the wet season, the wet season distribution of elephants in the ecosystem is largely unknown (but see Savidge, 1968).

In December 2013, Southern Tanzania Elephant Program (STEP) began an elephant monitoring program in Ruaha National Park to increase scientific understanding of the demography (Jones *et al*., 2018), ecology, and behaviour of the Ruaha elephant population. A primary aim of this program was to investigate elephant distribution and seasonality in the ecosystem using monthly vehicle transects to collect elephant sightings and dung density data. In this study, we used hotspot analysis to identify key elephant areas and resources and to describe differences in elephant distribution between seasons and years and by sex.

METHODS

Study area

STEP's elephant monitoring program is located in Ruaha National Park (20,226 km^2), in south-central Tanzania. Geologically, the park is composed of a lower basin (750-900 m) – an arm of the Great Rift Valley through which the Great Ruaha River flows – and a higher plateau area (1000-1500 schm). The park lies at a convergence zone between two vegetation types, with the Zambesian (miombo-dominated) zone occurring in the south and the Sudanian (*Acacia*) zone in the northeast (Bjornstad, 1976). The park also has extensive *Commiphora-Combretum* and *Terminalia* woodlands, and *Adansonia* dominated plains in the central areas (Bjornstad, 1976).

Ruaha experiences a tropical semi-arid climate with one dry season (May to November) one wet season (December to April), with most rain falling between December and March (Bjornstad, 1976). Average rainfall is 650 mm, and the southwest of the park typically receives more rainfall than the northeast (Bjornstad, 1976). The park is bounded by two major rivers which are important sources of water for wildlife: the Mzombe river in the north and the Great Ruaha river in the south (Stolberger, 2012). The park also has many sand rivers and springs which form important dry season water sources away from the main rivers (Stolberger, 2012).

Data collection

To collect data on elephant distribution and seasonality, elephant sightings and dung along a network of nine road transects (Figure 1) driven monthly were recorded. These transects cover a large portion of the elephant range in Ruaha that is currently accessible by road. Transects were driven at a speed of 30 kph with two observers (one on each side of the vehicle). Sampling of elephant dung using a strip transect method, recording all dung aged <1 week within 1 m of the transect line (defined as the middle of the road) was done. Elephant sightings were collected using the distance line transect method, with a perpendicular distance recorded to the centre of the group from the transect line. The locations of all dung and elephant sightings were georeferenced using a Global Positioning System (GPS) unit.

Data analysis

Elephant dung data were used to investigate elephant distribution and seasonality, because direct sightings of elephants are affected by differences in detectability of elephants in different habitats. Significant clusters of dung along the road transect network for four seasons (early dry, late dry, early wet, late wet) and two years (2016 and 2017) were detected. Analysis included six transects for which effort was similar during the wet and dry periods between February 2015 and October 2017, these six transects were each conducted 17-18 times in the dry season and 7-15 times in the wet season (Table 1). The total distance covered was >10,000 km. Optimized Hot Spot Analysis in ArcGIS 10.5 (ESRI, 2017a) using the Getis-Ord Gi* statistic to identify statistically significant hotspots of elephant dung was used. The input field was point data of elephant dung observed on the 2m-wide strip transect. The COUNT_INCIDENTS_WITHIN_FISHNET_POLYGONS scheme to aggregate dung point data into a fishnet polygon mesh (cell size was computed automatically by the tool using algorithms outlined in ESRI 2017b). A bounding polygon to define survey coverage (namely a feature layer of the transect network) was provided. The Getis-Ord Gi* tool analyses each feature in the dataset being investigated and determines whether each feature is a hotspot depending on the value assigned to the feature and its neighbouring features (ESRI, 2017c). Results from the Gi* statistic were automatically corrected for multiple testing and spatial dependence using the False Discovery Rate (FDR) correction method. The Gi* statistic output is a z-score for assessing statistical significance: for features that are determined to be significant hotspots, the z-score is larger (ESRI, 2017c).

Table 1: Distance and survey effort for six vehicle transects in Ruaha National Park

Transect	Length (km)	Dry season repeats	Wet season repeats
Jongomero-Msembe (MT1)	65.7	18	15
Msembe-Lunda (MT2)	82.7	18	15
Mwagusi (MW)	20.9	18	13
Mdonya (MD)	45.1	17	13
Mpululu (MP)	85.7	17	10
Magangwe (MG)	62.6	18	7

To investigate potential sex differences in use of the ecosystem, we identified statistically significant hotspots of bulls and cow-calf groups. Using ArcGIS Pro 1.2 (ESRI, 2017d) we first created Kernel Density maps of cow-calf groups and bulls using sightings data from February 2015 to May 2017. We applied a Filter Tool to account for variable effort between transects (this tool smooths the value of each grid cell generated from the Kernel Density tool, thereby reducing the likelihood of spurious values resulting from differential effort (Rechsteiner *et al.*, 2013). Using the geodesic projection in the Kernel Density tool, the density per kilometre squared for the bulls and cow-calf groups for each season was calculated. The Getis-Ord Gi* tool was then used to determine statistically significant hotspots using the Kernel Density measures.

RESULTS

The spatial clustering of hotspots of elephant dung varied between seasons and between years. Dry season hotspots were clustered in the Mdonya, Msembe, Mwagusi, Jongomero,

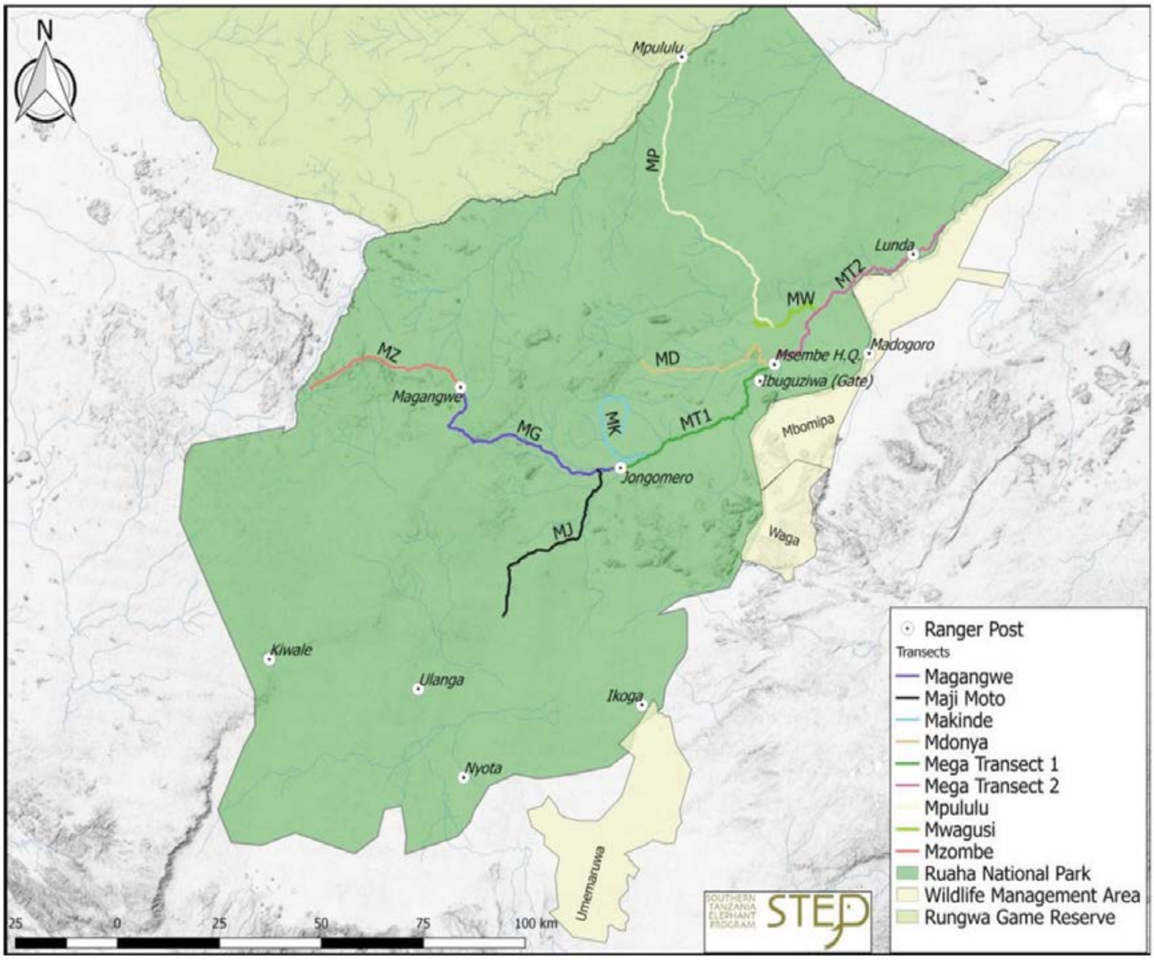


***Figure 1**: Map showing STEP's network of road transects in Ruaha National Park.*

Lunda and Itiku areas (Figures 2-3). The wet season hotspots clustered along the Great Ruaha River (Msembe to Ruaha-Mwagusi Confluence), and along the Mwagusi and Mdonya Rivers (Figures 4-5). Some hotspots were consistent between seasons (Mdonya, Jongomero), while others were wet (Msembe to Ruaha-Mwagusi Confluence) or dry (Itiku, Lunda) season hotspots. Between years, the clustering pattern of wet season hotspots was more consistent than that of dry season hotspots. One exception was the early wet season of 2017, for which the pattern of hotspots resembled that of the late dry season. Some dry season hotspots were consistent between years (Mdonya, Jongomero), while others were present in only one year (Itiku, Lunda). Many hotspots were located near tourism camps and/or ranger posts. Evidence of both spatial overlap and segregation in the locations of hotspots for bulls and cow-calf groups were observed (Figure 6). Bull and cow-calf group hotspots overlapped in the Msembe and Lunda areas. There was a distinct cluster of cow-calf group hotspots along the Mwagusi sand river, and two distinct clusters of bull hotspots located in Jongomero and Mdonya.

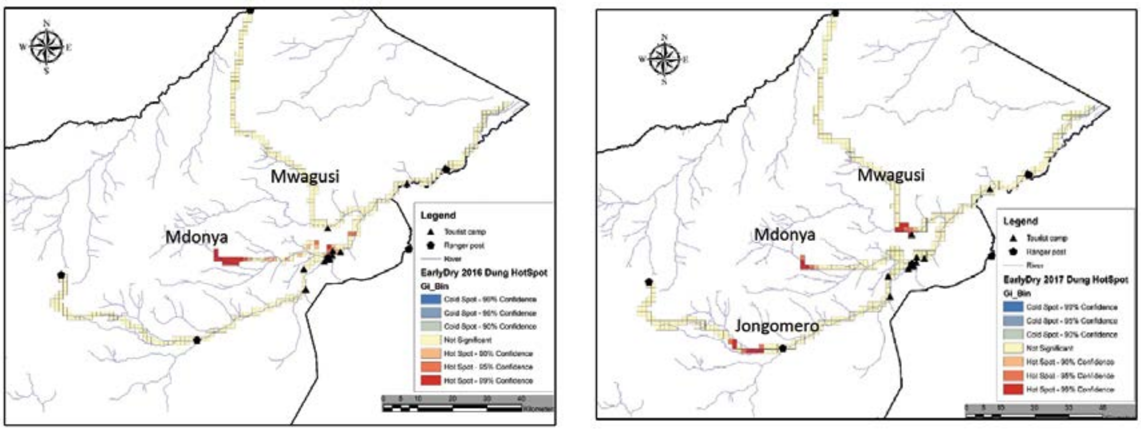


***Figure 2**: Location of dung hotspots in the early dry season (May-Jul) in (a) 2016 and (b) 2017*

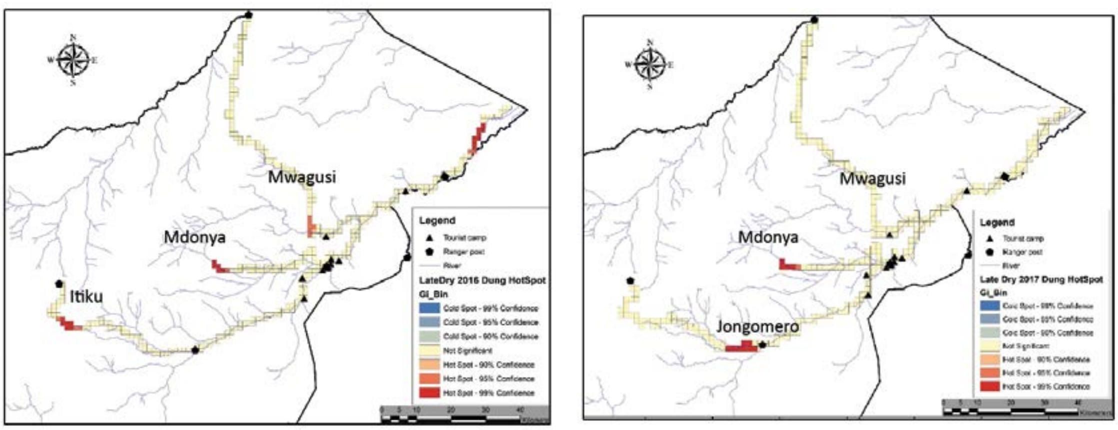


***Figure 3**: Location of dung hotspots in the late dry season (Aug-Oct) in (a) 2016 and (b) 2017*

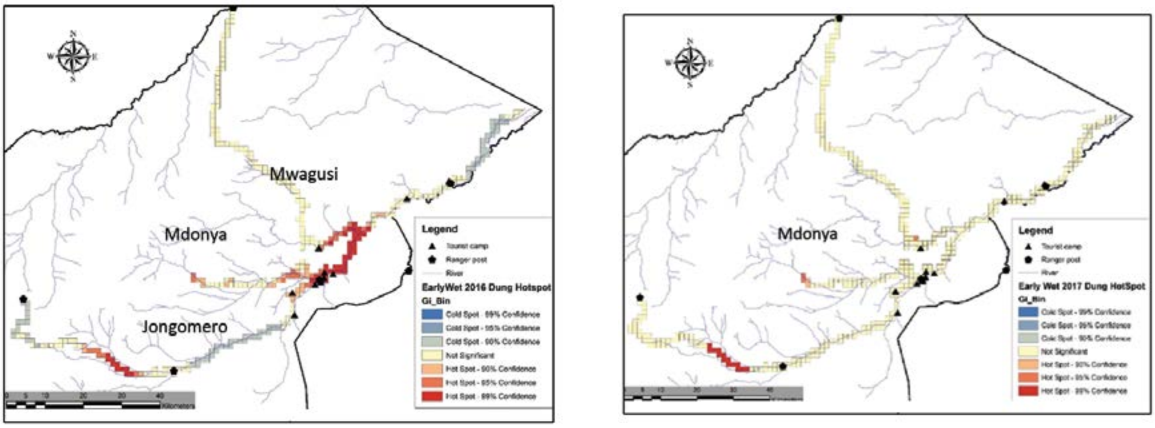


Figure 4: Location of dung hotspots in the early wet season (Nov-Jan) in (a) 2016 and (b)

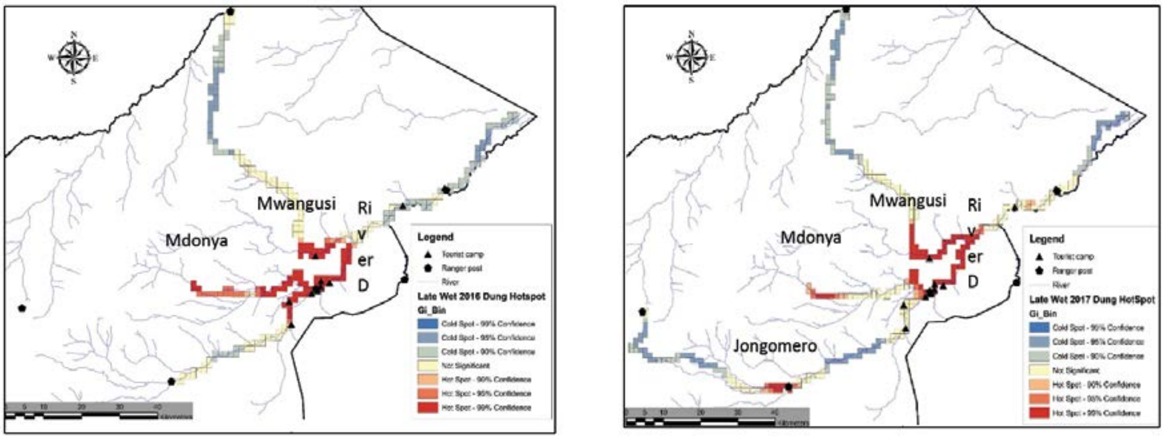
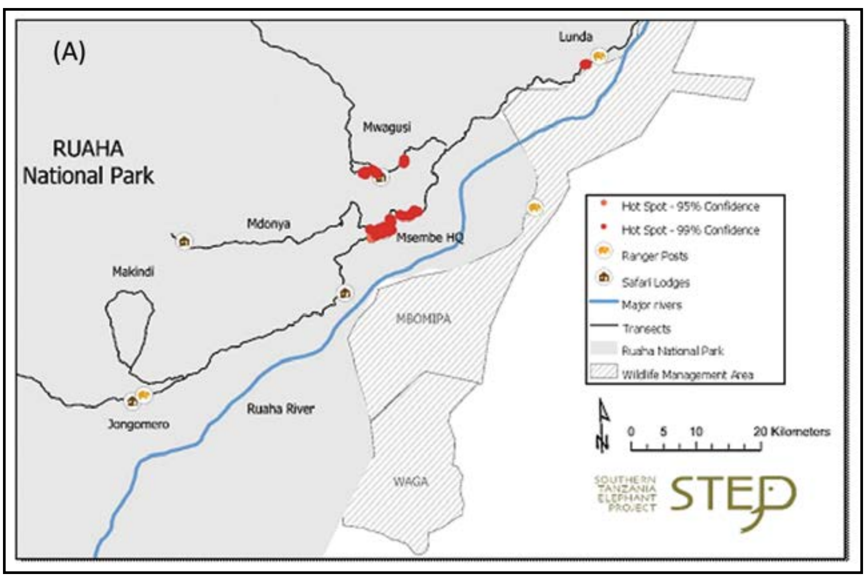


Figure 5: Location of dung hotspots in the late wet season (Feb-Apr) in (a) 2016 and (b)



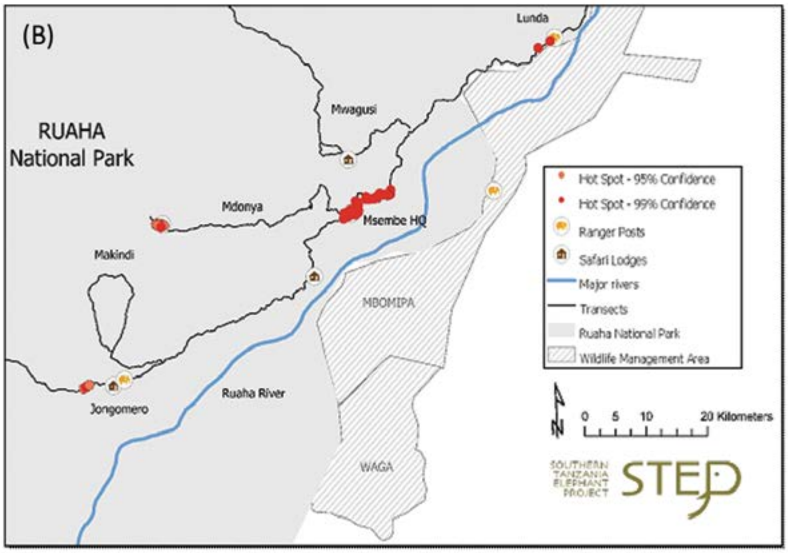


***Figure 6**: Location of hotspots of a) cow-calf groups and b) bulls in Ruaha National Park, from sightings of 2,001 cow-calf group individuals and 500 bulls between February 2015 and May 2017*

DISCUSSION

Data from vehicle transects to describe seasonal patterns in elephant use of Ruaha National Park was used. Our monitoring indicates that the Ruaha basin is used year-round by elephants, but that hotspots of elephant use vary locally between seasons and between years. In line with our findings, monthly aerial surveys conducted in the Ruaha basin from 1965-1966 showed year-round elephant presence, with densities peaking in the late dry and the late wet season (Norton-Griffiths, 1978).

Our monitoring also suggests that Ruaha's miombo areas are important year-round habitat for elephants. In 2016-2017, dung densities on the miombo-dominated Magangwe transect were comparable to densities along the Great Ruaha River (STEP, unpublished data). While this result should be interpreted with caution due to potential differences in elephant dung production and dung decay rates between these areas, historical data from aerial surveys in 1972-1973 also found some high-density elephant areas in Ruaha's miombo region (Norton-Griffiths, 1978).

Hotspot analysis revealed statistically significant clusters of elephant dung in areas with important water and food resources. Dry season hotspots were clustered along water sources, including the Great Ruaha, Mdonya, Mwagusi, Jongomero, and Mviringi Rivers, and mbuga drainage lines such as the Itiku. Water is an important resource for elephants and has been found to be the key determinant of dry season ranging patterns (Young *et al*., 2009). Cow-calf groups typically stay in close proximity to water during the dry season but may range further during the wet season when surface water is more widely available

(Stokke & du Toit, 2002). The majority of hotspots were located along sand rivers where elephants dig for water flowing below the surface (Stommel *et al*., 2016; STEP unpublished data). Elephant digging of waterholes in Ruaha (Stommel *et al*., 2016) and Namibia (Ramey *et al*., 2013) was found to be an adaptive behaviour to avoid the ingestion of poor quality surface water contaminated with faeces and pathogens, as well as for accessing water when surface water was absent.

The clusters of late dry season hotspots were also in areas with important forage resources. The Mdonya and Jongomero hotspots, for instance, are in areas with extensive *Acacia/Faidherbia* woodlands. In August and September, when trees such as *Acacia tortilis* and *Faidherbia albida* are producing pods, large numbers of elephants feed in these woodlands (STEP, unpublished data). This is also the peak time for elephants debarking trees, as this is related to new flower and leaf growth (Barnes, 1982a).

The distinct differences in hotspot locations in the early wet season between 2016 and 2017 may be related to spatial and interannual differences in rainfall, as well as the influence of the the El Niño-Southern Oscillation. The early wet season of November 2015-January 2016 experienced high rainfall due to the El Niño (Abdi *let al*., 2016; UNOCHA), and thus the pattern of hotspots resembles that of the late wet season of 2016. By contrast, the early wet season of 2017 received unusually low rainfall, resulting in very low wet season flows in the Great Ruaha River (Stolberger, 2017). These dry conditions of the early wet season in 2017 may explain why the pattern of hotspots for this period resembles a late dry season pattern.

The pattern of dung hotspots in the late wet season was similar between years, with hotspots clustering along the Great Ruaha River between Msembe and the confluence of the Ruaha and Mwagusi rivers, as well as along the Mwagusi and Mdonya sand rivers. We suspect these hotspots are related to wet season food resources, as grasses and herbs form 75% of elephant diet during the wet season (Barnes, 1982a). Grasses are plentiful in these areas during the wet season, and we regularly observe large temporary aggregations of elephants feeding in these areas during the late wet season months (STEP, unpublished data). These aggregations may also be forming for social reasons such as reaffirmation of social bonds and information sharing (Moss, *et al*, 2011), as well as increasing access to mating opportunities as most elephant sexual activity in Ruaha occurs during the wet season (Barnes, 1982b, STEP unpublished data).

Hotspots of elephant use tended to be dispersed in space during the dry season but showed greater clustering in the wet season. This was perhaps the result of seasonal differences in vegetation productivity, spatial heterogeneity in productivity, and levels of competition (Young *et al*., 2009), which we will investigate in future work.

Many hotspots of elephant use were in areas with tourism camps or ranger posts, suggesting that elephant ranging behaviour in Ruaha is also shaped by risk avoidance (primarily from poaching for the ivory trade). Analysis of elephant carcass densities in Ruaha-Rungwa revealed that poaching risk was unevenly distributed in space (Beale *et al*., 2017). Overall, elephant carcass densities were lower near tourism camps and ranger posts (Beale *et al*., 2017), suggesting that these areas provided relative safety from poaching for elephants.

In many populations of African elephants, females and males show differences in their use of space and resources, because of differences in resource requirements and constraints (Stokke & du Toit, 2002; Shannon *et al*., 2006). In Ruaha, we observed both spatial overlap and segregation in the location of bull and cow-calf group hotspots. The overlap in Lunda likely results from the presence of a large, semi-permanent aggregation of elephants in this area, which includes cow-calf groups and bulls (STEP, unpublished data). In the Msembe area, bulls and cow-calf groups are present and form mixed groups year-round (STEP, unpublished data). The two distinct bull areas identified in our hotspot analysis are in Jongomero and Mdonya, both of which lie in areas with tourism camps and are home to semi-resident bull groups (STEP, unpublished data).

This paper presents a first look at elephant seasonality in Ruaha National Park and provides a baseline for future monitoring. We intend to build on these initial results by identifying key predictors of hotspots of elephant use and by analysing elephant distribution data from STEP's aerial monitoring of roadless areas. We anticipate that satellite-tracking data from a study of collared elephants by the World Elephant Centre will be complementary to this work, and further increase our understanding of the seasonal movements of elephants in Ruaha National Park.

ACKNOWLEDGEMENTS

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AN ECO-FRIENDLY APPROACH TO TACKLE AFRICA'S DECLINING APE POPULATIONS

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ABSTRACT

The prospect of extinction of Africa's Great Apes, humankind's closest living relatives, has been gaining momentum over the past few decades. All African Great Ape species (chimpanzees, bonobos, eastern gorillas and western gorillas) are assessed as endangered or critically endangered on the IUCN Red List. Forest habitat fragmentation and loss due to infrastructure development, commercial logging, the use of forest biomass for making charcoal, gathering of wood fuel and clearing of land for agricultural plots all contribute towards this situation. These activities increase access into once remote, inaccessible habitats, leading to more hunting for meat, trophies and live infants, and fostering human-ape cross-species infectious disease transmission. The combined effects of these anthropogenic factors on Great Ape populations are much greater than the sum of their individual parts. For our chimpanzee research program, we have designed and tested an eco-friendly approach aimed at conserving the eco-structure. We have designed, constructed and tested a completely solar-powered laboratory that leaves minimal environmental footprint, based on the concept of bio-mimicry. In 2008, the lab was transported to Mahale Mountains National Park where it remains in situ to support scientific research on Mahale chimpanzees, to educate tourists on key chimpanzee conservation challenges and as an emergency touch point for Park staff and visitors in need of a reliable power source and communication network in this remote environment. There is no question: infrastructure is required for development, ecotourism and protecting and studying declining ape populations and other wildlife species. After 6 years of field testing, our field laboratory has successfully served as a base camp from which to tackle these challenges and promote research and conservation in the 21st century.

Key words: *Chimpanzees, field laboratory, field studies, Great Ape diseases, Mahale, Tanzania.*

INTRODUCTION

Several factors contribute to declining numbers of Africa's Great Apes. These include, forest fragmentation and loss due to infrastructure development, commercial logging, the use of forest biomass for making charcoal, gathering of wood fuel and clearing of land for agricultural plots. Further, these activities increase access into once remote, inaccessible habitats, leading to more hunting for meat, trophies and live infants, and fostering human-ape cross-species infectious disease transmission. Combined effects of these activities are much greater than the sum of their individual parts. The Mahale Mountains are located in the Albertine Rift Valley in western Tanzania (Figure 1). The Mahale area is home to the largest remaining population of eastern chimpanzees (*Pan troglodytes ssp. schweinfurthii*). Estimates suggest there are somewhere between 700 and 1,200 chimpanzees residing there. It is a remote and isolated area, only accessible by air or boat. This overall remoteness and lack of access by road to Mahale has been invaluable from a conservation standpoint.

In 1965, human habituation of the so-called M-Group of chimpanzees began by the Kyoto University Africa Primatological Expedition. Twenty years after Japanese primate researchers established their first research camp at Mahale, 1,613 square kilometers (623 square miles) gained National Park status. The Park is remote, about 128 km south of Kigoma town, and accessible only by air and boat (Figure 1). Both eastern and western flora and fauna flourish on the island peninsula bordering Lake Tanganyika, with about 75% of the Park being miombo woodland. The chain of mountains runs northwest to southeast and the highest peak in the montane forest rising 2,462 meters above sea level. The Park is a foot-walking park. Traversing the mountains can only be accomplished on foot, or swinging hand-over-hand through the thick montane forest. Baboons and vervet, colobus and red-tailed monkeys are other indigenous primates found at Mahale.

The M-Group chimpanzees have become a major attraction for tourists who come from around the world just to see them up close in their natural habitat. Tourist camps have also emerged at Mahale and the total number of visitors has increased by about five-fold between the years 2000 and 2007 (Figure 2). At the same time, the size of local human populations also increased adding even more pressure on the ecosystem. Habitat fragmentation and loss occurred due to infrastructure development, the use of fo rest biomass for making charcoal, gathering

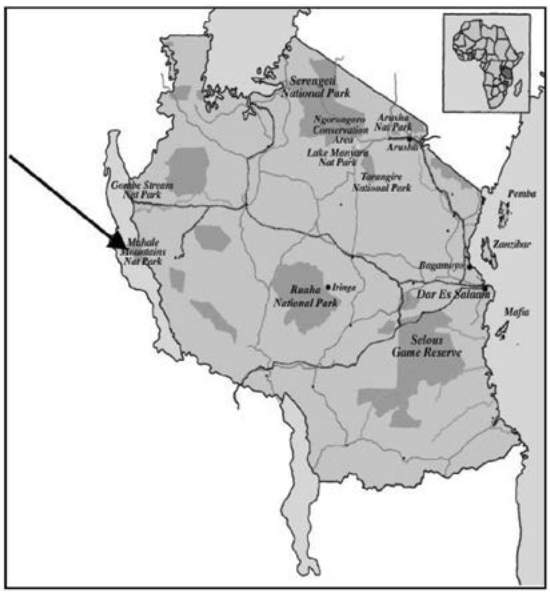

Figure 1. *Location of Mahale Mountains National Park along the eastern shore of Lake Tanganyika in western Tanzania (arrow).*

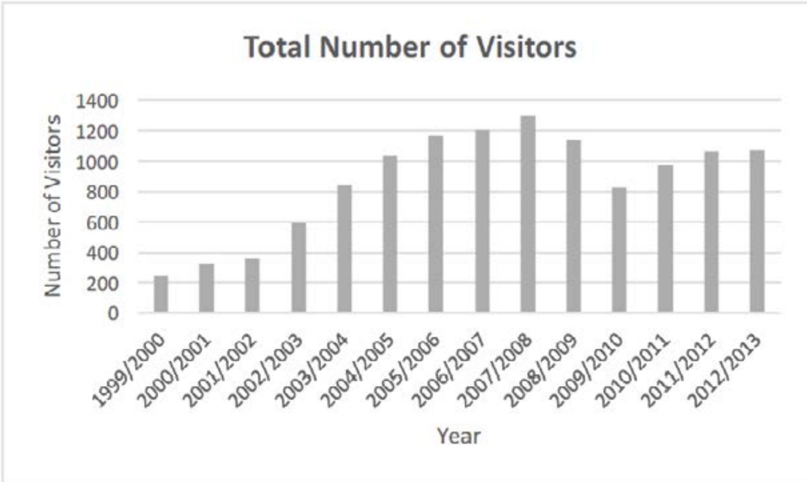

Figure 2: *The number of visitors at Mahale Mountains National Park increased between the years 2000 and 2008 to a maximum of 1293 visitors, declined and increased again reaching 1074 visitors in 2013 (TANAPA 2008, 2018).*

of wood fuel and the clearing land for agricultural plots. Census records dating back to 1980 show that chimpanzee number in the M-Group was initially increasing; however, population size gradually began declining and reached an all-time low of 45 in 1997. In the five-year period from 1993 through 1997 alone, the population was reduced by 41%. There was some recovery over the subsequent 10-year period, although only by 31%. Acute and fatal respiratory illnesses, contagious in nature, accounted for about 41% of reported mortality in the M-Group (Figure 3).

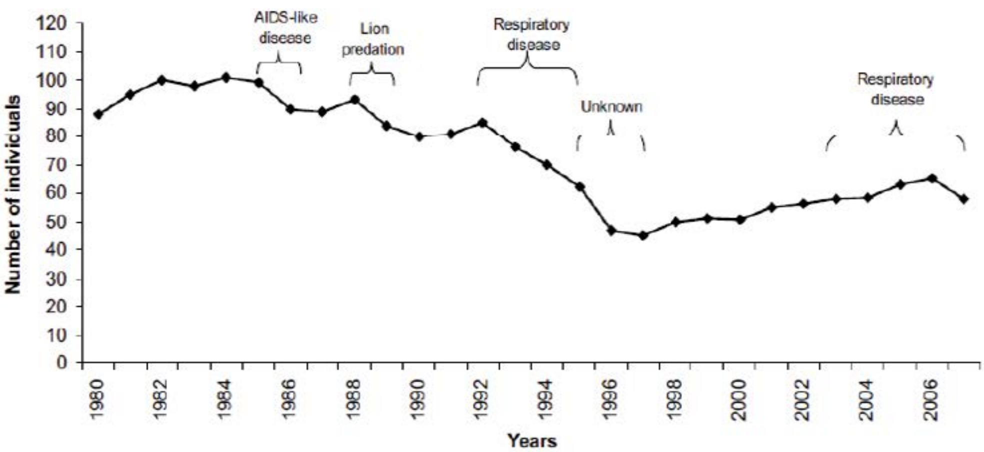

Figure 3: *Observed causes of mortality in M-Group chimpanzees (T. Nishida, 2007).*

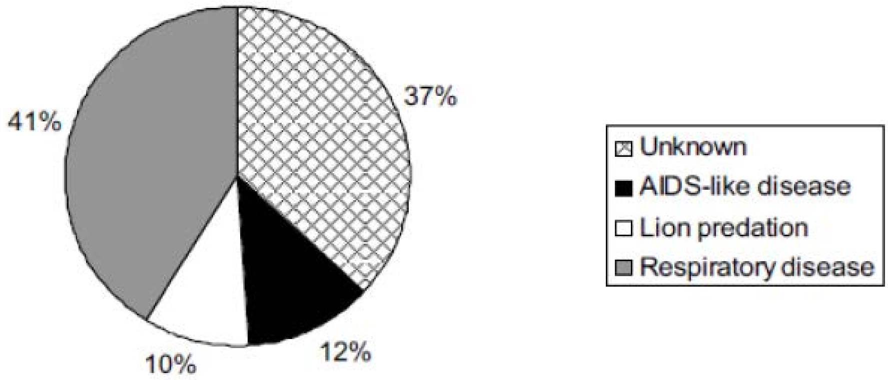

Figure 4: *Respiratory disease accounts for 41% of mortality in the M-Group between 1980 and 2006 (T. Nishida, 2007).*

In 1996, the Eastern subspecies of chimpanzees was added to the IUCN Red-List of chimpanzee sub-species assessed as *endangered* (at a very high risk of extinction). Because human and chimpanzee DNA sequences only differ by less than 2%, similarities between the two species increase the risk of cross-species transmission of infectious pathogens, with subsequent morbidity and mortality (i.e. influenza, tuberculosis, measles, parasites and others). Together with the Japanese researchers, we conducted outbreak investigations on three acute and fatal respiratory disease outbreaks in M-Group chimpanzees, studying the epidemiology and causative infectious agents. In the early 2000's at Mahale, however, our research was hindered lack of research infrastructure, slow unreliable transportation, lack of a renewable energy source and an appropriate enclosure for the equipment necessary to analyze samples and data. Thus, we were challenged by the need to conduct "space age science" with "stone age tools"; and thus, made a call to action. Here, we describe the prototype field laboratory designed and built to facilitate the conduct of biomedical research in such a remote, difficult-to-reach area.

METHODS

Our research team worked in collaboration with architects and interior and industrial designers to create a prototype portable laboratory, with design criteria that would facilitate the conduct of research in the remote semi-evergreen gallery forest in Tanzania's Mahale Mountains (Latitude 6˚S, Longitude 30 ˚E). Our overall objective was to overcome obstacles that limited the scope of scientific inquiry in this geographically remote and relatively inaccessible location. We needed to store, process and analyze biological samples under optimal conditions. Thus, we set out to develop a unique and innovative environmentally sensitive and responsive, solar powered, portable high-performance laboratory with near-zero environmental impact.

Using biomimicry as an initial design direction, the design concept emerged, one which would leave no environmental footprint. Our team developed a portable laboratory (*maabara ya kuhama*) that could migrate with project needs and the data-trail into remote and environmental sensitive ecosystems without disturbing the native environment. Preservation of the thriving ecosystem of this endangered species was a driving force. We combined a field-ready laboratory with a comfortable field-appropriate dwelling space using a novel environmentally-friendly approach. Key programmatic elements included an autonomous renewable energy-source, a lightweight and portable frame, and versatile structure capable of responding to macro-climatic conditions while remaining environmentally low impact. Maabara ya kuhama was field tested in the US and then packaged for transatlantic shipment for further *in-situ* testing at Mahale.

RESULTS

Deploying a portable laboratory in an environmentally sensitive, remote area that lacks transit, mechanical or communication infrastructure demands structural systems with minimal weight, simple field-ready assembly processes and maximum strength. Two limitations were primary in addressing these design criteria. One being the reasonable limit of a tool-less assembly process. This is relative to a conventional tool-dependent assembly process. The second limitation deals with a classic challenge of enclosing large volumes with minimal structure, and at the same time, be a two-person, tool-less assembly process. To this end, a steel-sleeved-fiberglass rod structure was designed as the superstructure of a large, enveloping tent enclosure.

A series of modular T6061 aluminum moment frames act as the chassis of the laboratory and sleeping loft. Connectivity of the frames was achieved through a two-tool-less assembly process and was possible by two people. The foundation of the building consists of four steel screw jacks that provide a high range of adjustability. The frame is constructed using a unique custom hand screw and draw latch combination that allows complete assembly without use of tools. Once assembled, aluminum skinned EPS (Expanded Polystyrene) structural insulated panels are added to the frame and serve as wall and floor panels. Each wall is secured to the frame using custom tool-less fasteners. Upper level floor panels form the ceiling of the enclosure and provide the second floor sleeping loft area. They are finished with a light gauge brushed aluminum and cork. The brushed aluminum allows light (not heat from the exterior) to be reflected into the space so electric lights are not needed.

DISCUSSION

After 8 months in development and application during initial testing in the US on the campus of Virginia Polytechnic Institute and State University, the behavior of the novel fiberglass steel composite structure in long-span applications proved to be temperamental. Dynamic loading in end-conditions began showing stress between the adhesive bonded fiberglass and steel sleeve connections. Although conventional mechanical connections easily reinforce the adhesive bonded connections, they include a cost of weight and complexity that the adhesive bonded connections avoid. The aluminum skinned EPS panels on the first floor and chassis assembly bars bear the loads of wall panels, while the upper level floor panels bear on the upper chassis and walls (Plate 1).

The foundation jacks allowed the laboratory to occupy a space with minimal impact to the soil it stands on. The structural chassis frames the lower laboratory space and supports the fabric superstructure. The lower level also includes modular counter space and storage. Four translucent, sliding polycarbonate doors protect the entry to this level. Additionally, the control unit for the separate photovoltaic arrangement is located on the end wall of this enclosure. As an extension of the interior laboratory space a collapsible deck extends from either side of the structure. The decking, when removed, can be attached across the laboratory entrances providing additional security to the structure.

A lightweight modular frame system made of one-inch diameter pultruded structure fiberglass rods is the superstructure of the enveloping fabric enclosure. The fiberglass rods are joined using a unique system of steel sleeves, methyl methacrylate adhesive, and cast iron pipe connectors. An abrasive resistant rubberized coating protects each

Plate 1: Pre-deployment set-up testing of the lab on the Virginia Tech campus prior to shipment.

fiberglass rod. The tent superstructure is comprised of five main groups: an end frame that supports the long space ridgepole, that extends four feet beyond the structure at either end. On each side, a curved frame ties into the ridgepole and provides support for the deck enclosure.

The lower space was divided into three areas. The control center, a clean room and a swing space. The control center accommodates the photovoltaic electric panel board, associated hardware, umbilical and heavy electric-load items, such as freezers, refrigerators and universal multi-port charging stations. The clean room is a sealable lab space that accommodates typical biological analytical equipment. If need be the swing space can spill over and back between the clean room, the control room and the exterior decks and can accommodate activities, such as group meetings and exhibits.

The tent provides rain and wind protections for the lab-box and allows the roof of the lab-box to act as a second floor for sleeping quarters. It also acts as a solar shade and helps reduce radiant gain on the laboratory space. The fabric is a special fire-retardant treated polyester-nylon weave that allows the space to breathe, yet blocks UV radiation. Long axis ends have operable flaps for air circulation. This enclosure effectively triples the protected area by providing a covering for each deck and the second level living space. Optional panels provide additional protection to the opening around the deck and to the upper level living space. Insect and spill protection is provided by a netting that attaches to the perimeter of the upper level and fabric above.

In 2007, laboratory components, along with a boat and other supplies were loaded into a container for the transatlantic part of the

Plate 2: Team members manually unloading container in Kigoma, Tanzania. A boat was included to support local transport for research activities at the Mahale Mountains.

Plate 3: Laboratory components and team members loaded into alocal boat for transport down Lake Tanganyika to the Mahale Mountains.

Plate 4: Preparations for off-loading laboratory components at Mahale Mountains National Park.

journey from Norfolk, VA to Dar es Salaam, Tanzania. The container was transported by road to Kigoma and offloaded manually and transferred to a wooden boat for the 12-hour journey down Lake Tanganyika to Mahale (Plate 2 and 3).The laboratory at Mahale was successfully set-up by a tool-less assembly process by two people, where it remains *in situ* until today (Plate 5 and 6). It's uses have included scientific research on the disease status of the Mahale chimpanzees, education for tourists and students on conservation challenges and as an emergency touch point for Park staff and visitors in need of a reliable power source and a communication network in this remote environment. After six years of field testing at Mahale, the lab design has proven to be a potential solution as a base camp to tackle challenges associated with advanced research on the decline of Great Ape populations. Our scientific discoveries using this lab have to support chimpanzee research have included, a human metapneumovirus as the causative agent of acute and fatal respiratory disease in Mahale chimpanzees, a novel species of Campylobacter (*Campylobacter troglodytes*), and well as two adenoviruses and a rotavirus. The solar array was also used by others at the Park, including a Korean Film Crew, tourists and park and tourist camp staff. There is no question that field-appropriate portable infrastructure can accommodate biomedical investigations on the chimpanzees, as well as a number of other field activities.

The wet lab area has a designated bench-top area with necessary equipment to manage day-to-day laboratory activities required for sample collection, processing and storage. The dry lab area provides a sizable solar power system able to support modern laboratory equipment, as well as provide internet connectivity and support the latest computer technology for reliable and timely local and international communications. In closing, this prototype field laboratory provides a portable field infrastructure with a renewable energy source and modern technology to support any number of activities, including research, surveillance, outbreak investigations and responses and clinical diagnostics. The laboratory's longevity, durability and periodic maintenance could easily be addressed with funding for full-time (annual) on-site representation (occupancy).

Plate 5: Portable Lab, satellite dish and solar hut in situ at Mahale Mountains National Park, Tanzania. Wet lab is in-use by our local staff. In the dry lab, a junior research scientist is on an international call.

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IMMOBILIZATION OF FREE-RANGING IMPALA (AEPYCEROS MELAMPUS): EXPERIENCE FROM THE SERENGETI ECOSYSTEM, TANZANIA

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ABSTRACT

Chemical immobilization of wildlife is widely used for research and translocation purposes worldwide. Two immobilization protocols for capturing impala in the Serengeti ecosystem were compared involving six females in each protocol. The first drug combination protocol consisting of 4±0.81mg etorphine hydrochloride and 30±21.7mg xylazine hydrochloride was used in the Serengeti National Park and Ikorongo-Grumeti Game Reserves. The second drug combination protocol consisting of 2.3±0.5mg etorphine HCl, 3.3±0.8mg medetomidine HCl and 18.3±4mg azaperone tartrate was used in the Serengeti National Park, Loliondo Game Controlled Area and Ikorongo-Grumeti Game Reserves. Diprenorphine HCl, atipamezole HCl and yohimbine were used as reversal drugs in both protocols. Concurrently, physiological parameters including rectal temperature, respiration rate, oxygen saturation and heart rate were monitored in both protocols. Our results showed that both protocols were efficient in the national park where impala are less stressed while in disturbed areas only the second protocol was efficient. Time of induction and recovery for first protocol was 6±2.9 and 2.5±1.45 minutes and for the second protocol was 3±0.7 and 2±0.5 minutes respectively. We recommend that for effective immobilization of impala even in areas with high anthropogenic disturbances, the second protocol should be used due to short induction time and reduced mortality risk because of low dosage of etorphine HCl.

Key words: *Anthropogenic disturbance, impala, immobilization, protected areas.*

INTRODUCTION

Impala (*Aepyceros melampus*) are medium–sized African species of antelope that play a significant role in extensive ecosystems in the sub-Saharan region (Zeiler et al., 2015). Impala are gregarious, mixed feeder (grazer and browser) but are predominantly grazers while grasses are green and growing; browsing foliage, forbs, shoots and seedpods at other times and when need be it also eats fallen dry leaves. The antelope is sexually dimorphic with full-grown adult males and females weighing 60-65kg and 45-50kg respectively (Averbeck, 2002). The group size is related to food availability and dispersion prefer light woodland with little undergrowth and grassland of low to medium height and thus varies seasonally, as do other features related to feeding behavior such as rate of movement and inter-individual distance (Setsaas *et al.,* 2007).

Where cover and open water are available the herds may be made up of adult and juvenile ewes with juvenile rams and some young non-territorial rams. The movement pattern and group size of impala is related to the availability of food and prefer fresh grasses and leaves but to some extent feeding on dry leaves (Setsaas *et al.,* 2007). Impala are regularly captured for disease monitoring, clinical treatment and translocations during routine management procedures. Several drugs have been used successfully to immobilize this medium-sized antelope (Arnemo *et al.,* 2014; Kreeger *et al.,* 2002) etorphine hydrochloride in combination of xylazine hydrochloride.

Chemical capture and general anaesthesia are among the most challenging procedures when routine veterinary interventions are required in wild antelope (Zeiler & Meyer, 2017). Many factors need to be considered to ensure success including environmental conditions, drug and drug delivery systems and animal characteristics (Arnemo *et al.,* 2006). During chemical immobilization it is important to ensure that the induction and recovery time is kept as short as possible (Fyumagwa *et al.,* 2012). To facilitate this effect, most immobilizing agents are combined with either a sedative or tranquilizer to harness their synergistic effect and this is important because it enables decrease in induction time and reduction of potential side effect at lower doses of immobilizing agents (Fyumagwa *et al.,* 2012).

Twelve impala were immobilized in the Serengeti National Park (SNP), Ikorongo-Grumeti Game Reserves (IGGRs) and Loliondo Game Controlled Area (LGCA) between April 2016 and May 2017 for fitting GPS-Satellite radio collars for the study *of "Physiological and behavioral impacts of human disturbance on impala in the Serengeti Ecosystem"* with different management systems. The aim of this study was to establish an effective protocol for immobilization of impala in free ranging environment in the national park where animal are less stressed and in game reserves and game controlled areas that are facing high anthropogenic disturbances.

MATERIALS AND METHODS

Study area

This study was conducted in the Serengeti ecosystem which covers 25,000km^2, and is famous for the migratory wild herbivores mainly wildebeest (*Connochaetes taurinus*), zebra (*Equus burchelli*), Thomson gazelles (*Eudorcas thomsonii*) and eland (*Taurotraghus oryx*). The ecosystem consist of the exceptional resource values in the Serengeti National Park (SNP) with rich flora and fauna; a natural self-regulating ecosystem; endless grassland savanna plains; large predator-prey population and interactions (TANAPA, 2006). The ecosystem has cross border with different conservation administration between Tanzania and Kenya. The impala's immobilization exercise was conducted in three different areas namely SNP which covers 14 763km^2, being the country's second largest national park after Ruaha National Park (TANAPA, 2006) located in northern part of Tanzania (Figure 1). It lies in the west of the Rift valley, in highland of savannah regions with plains and woodlands ranging 900-1500m above sea level. Its western part extend close to Lake Victoria and bordering Maasai Mara National Reserve in Kenya to the north, Ikorongo-Grumeti Game Reserves (IGGRs) ca. 600 km^2 &400km^2, to the western respectively and Loliondo Game Controlled Area (LGCA) ca.4000km^2 on eastern side (Kaltenborn *et al.,* 2011).

SNP is conserved for photographic tourism only and is under Tanzania National Parks (TANAPA), and forms the core of the Serengeti ecosystem. The park is set aside to preserve the country's rich natural heritage, and provides secure breeding grounds where its fauna and flora can thrive with minimum conflicting interests of a growing human population. In IGGRs and LGCA on the other hand are managed by Tanzania Wildlife Management Authority (TAWA) for both photographic tourism and trophy hunting, putting wild animals at a higher stress levels compared to the former. Additionally, the LGCA unlike the IGGRs is a multiple land use area where settlement, cultivation and livestock keeping are all legally practiced.

Study animals

Immobilizing impala in three different locations with different management systems, necessitated development of protocols with proper dosage to avoid disappearance of darted animals prior to the onset of induction. Free ranging 12 adult female impala were chemically captured using two different protocols. Each treatment group comprised of six female impala. The first protocol was applied in SNP and IGGRs using etorphine and xylazine and the second protocol consisted of etorphine, medetomidine and azaperone and was applied in SNP, LGCA and IGGRs.

The drug combinations were remotely delivered using either Dan-Inject® or Pneu-dart® gun depending on the habitat and animal behavior. Three (3) mls Dan-Inject® darts with collared 2 mm × 25mm needles or 2ml x 25mm pneudart darts were used. All twelve animals were darted in either the left or the right hindquarters and dart sites were treated with topical oxytetracyline HCl antibiotic (Alamycin). Subsequent to that, collaring and collection of blood, fecal and hair samples for further studies was carried out.

Drugs used for Impala Immobilization

Etorphine HCL

Etorphine hydrochloride (6, 14-endoetheno-7alpha-(2-hydroxy-2-pentyl)-tetrahydro-oripavine hydrochloride) is a semi-synthetic opioid derived from thebaine and has

1000-8000 times the analgesic potency of morphine. Etorphine HCl is available in 9.8 mg/ml concentrations and is supplied in preformed polystyrene containers containing a 10 ml rubber-stoppered vial and a similar vial of diprenorphine HCl. Etorphine HCl is very dangerous opioid drug to handle, a long-acting and recovery can be prolonged due to enterohepatic recycling. Potentially fatal respiratory depression, regurgitation, poor muscle relaxation, hyperthermia and relatively long induction times are common adverse effect requiring close monitoring (Meyer *et al.,* 2008).

Medetomidine HCL

Medetomidine is a more potent a2-adrenoreceptor agonist than other a2-agonists like xylazine HCl or detomidine HCl (Walsh & Wilson, 2002) and it is available as a 10mg/ml to 20 mg/ml injectable solution , the adverse effect is bradycardia and a biphasic blood pressure response with an initial peripheral vasoconstriction followed by vasodilatation. It is commonly combined with opioids or cyclohexamines for anaesthesia and immobilization (Clarke & Trim, 2013).

Xylazine HCl

Xylazine is an alpha – 2 adrenoreceptor agonist and the most commonly used drug in the sedative analgesic category. The concentration of the drug used is from 20mg/ml to 100mg/ml solution, and 500mg powder form. It has many of the same effect as the opioids without the CNS stimulation in which it produces muscle relaxation and sedation (in most animals) and analgesia.

Azaperone Tartrate

Azaperone is a butyrophenone tranquilizer, and mild muscle relaxation without analgesia, but is not potent enough to be used alone, and is available as a 40mg/ml to 100mg/ml commonly used adjunct to opioid induced chemical restraint in herbivores. In these combinations the dose is from 0.15 -0.30mg/kg body weight, as adverse effect may cause hyper-salivation, tremor, and tachypnea.

Reversal drugs after immobilization

Reversibility of anaesthetic drugs is important in case of adverse effects or if wild animals have to be released into the wild. The reversal drugs also help to reduce the time spent by operators to wait for recovery of chemically immobilized animals.

Diprenorphine HCl

Diprenorphine is supplied with etorphine hydrochloride as its antidote by the manufacturer available as 12mg/ml injectable solution is a partial opioid antagonist for etorphine and should be used only if full antagonism of opioid effects is not required. It is used at a dose rate of 2-3times

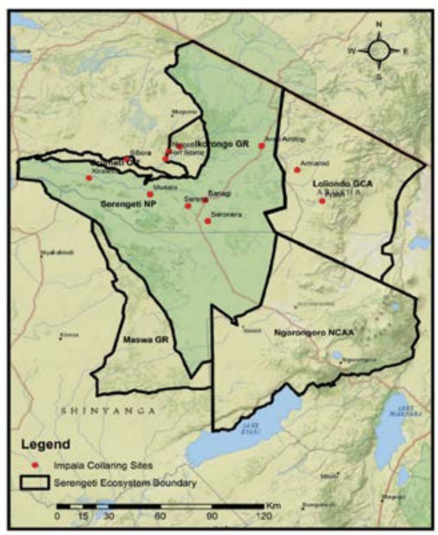

Figure 1: *Map of the Serengeti ecosystem showing impala capturing sites.*

the total dose of etorphine HCl to antagonise the immobilizing effects. For total antagonism, naltrexone HCl or nalorphine HCl are available, which are pure antagonists and are often available as human antidotes or for animals that require full antagonism like white rhino (*Ceratotherium simum*) and warthogs (*Phacochoerus africanus*) etc.

Atipamezole HCL

Atipamezole is a potent, selective, and specific alpha-adrenoceptor antagonist, exhibiting mainly alpha-2-adrenoceptor activity at both central and peripheral receptor and is available as a 5 mg/ml injectable solution. It is supplied in 10 ml multi-dose vials administered intravenous. Caution is required as these drugs may cause cardiovascular side effects (hypotension) and an excessive CNS stimulation.

Yohimbine HCL

Yohimbine hydrochloride is the indole-alkylamine alkaloid found in the bark of yohimbine tree (*Pausinystalia yohimbe*) and in the root of *Rauwolfia sp* it was obtained as a dispensed medicine in injectable solution of 6,25mg/ml in a 50ml vial, used as an alpha 2 antagonist indicated for reversal of the sedative effect of xylazine in a free ranging impala which provides a rapid and safe reversal of xylazine sedation in and easily administered intravenously at a dose rate of 0.2-0.3mg/kg body weight.

Immobilization protocols

Immobilization of impala in SNP was quite easy compared to LGCA and IGGRs where very coordinated communication with the scouts for spotting of impala flocks and once located using binoculars, the scouts communicated with the capture team. The later then proceeded to the area for assessment depending on the behaviour of the animal and terrain of the habitat. Where the terrain was good for immobilization, animals were approached to a suitable distance of about 30-40m and darted using Pneudart (Model 196, Pneu-Dart, Johannesburg, South Africa) or Dan-Inject (Dan-Inject CO_2 Injection Rifle Model J.M.ST, Dan-Inject international, Skukuza, South Africa) projectors. All the darts were positioned in the thigh muscles. Once the animal was recumbent it was place on sternal position and blindfolded to reduce external sensory stimuli as is common in capture procedure.

Three different methods were employed depending on the capturing location and behavior on flight initiation response of the respective impala

1. Slow approach of the animal by a vehicle in downwind directions with loaded dart-gun.
2. Following a herd of impala with a vehicle toward a shooter in hiding situation (stalking) this method was applicable in terrain with thick bushes which allows hiding areas
3. Chasing the animal in a high speed at a short distance while pointing the dart-gun from the vehicle's window was used in sufficiently smooth plains. This was specific in IGGRs and LGCA whereby animals can't allow shorter distances. Alternatively, a Pneudart® gun which is a long range rifle and capable of hitting a target up to 100metres was used.

RESULTS

A total of 12 adult female impala's were captured within Serengeti ecosystem. Whereby inside Serengeti National Park the total dosage of etorphine hydrochloride ranged from 4±0.81mg and 30±21.7mg of xylazine per animal. However, the second protocol applied in Loliondo Game Controlled Area and Ikorongo-Grumet Researves and SNP again had a combination consisting of etorphine HCL, medetomidine HCL and azaperone tartrate at a mean dose of 2.3±0.5mg, 3.3±0.8mg and 18.3±4mg respectively.

Early signs of induction in the first protocol such as stepping gait or hind limb ataxia and head lifting/ star gazing was observed within 6±2.9 minutes of darting to when an impala fell down and could not lift its head and the recovery time was 2.5±1.45 minutes. However, in the second protocol the induction and recovery time were shorter compared to the first protocol with mean of 3±0.7 and 2±0.5 minute respectively.

Table 1: Drugs dosage and time used to capture Impala inside SNP using two drugs combination (n=6)

Item	Mean±SD	Range
Etorphine(mg)	4±0.81	3-5
Xylazine (mg)	30±21.7	10-60
Body wt(kg)	47.9±2.7	45-52
Down time(min)	6±2.9	2-4
Recovery (min)	2.5±1.45	1-5

Table 2: Drugs dosage, body weight and time elapsed during capture of Impalas in IGGRs and LGCA using three drugs combination (n=6)

Item	Mean±SD	Range
Etorphine (mg)	2.3±0.5	2-3
Medetomidine (mg)	3.3±0.8	3-5
Azaperone (mg)	18.3±4	10-20
Body weight (kg)	50±3	48-56
Down time (min)	3±0.7	2-4
Recovery (min)	2±0.5	2-3

Table 3: Observed physiological parameters in 12 impala from three different capturing sites using etorphine-xylazine (EX) and etorphine-medetomidine-azaperone (EMA)

Parameter	Protocol	First 10 min*	First 15min*
Heart rate (beats/min)	EX	48±18	45±11
	EMA	80±4	77±5
Oxygen sat. (SPO2%)	EX	88±5	85±5
	EMA	94±3	95±6
Resp.rate (beats/min)	EX	15±3	17±5
	EMA	23±5	25±4
Temperature (°C)	EX	38.8±0.5	39.5±0.3
	EMA	38.5±0.4	37.5±0.6

The drugs, dosage ranges and time of capturing are summarized in Table 1 and 2, which reflects a range of dosages evaluated to determine the effectiveness and safety of these drug combinations in a twelve free-ranging impala inside and outside the Serengeti National Park. During chemical immobilization the impala in SNP were less nervous and could be approached between 20-40m without attempt to escape, while in IGGRs and LGCA the flight initiation distance was high from 40m and beyond with very rare occasion when the distance was about 30m. Due to high flight initiation distance some of the impala in IGGRs and LGCA were captured using drop nets.

DISCUSSION

The selection of drugs for immobilizing impala was governed by the availability and partly by personal experience and the advice from other experts. Potent opioids, etorphine and thiafentanil, are considered the drugs of choice to induce immobilization in impala (Zeiler *et al* , 2017).When these drugs are used alone they result in muscle rigidity (a mu-opioid receptor effect), but can fail to fully immobilize impala, especially when conservative doses are used.

In this collaring exercise we have established that the best immobilization protocol for impala in Tanzania regardless of the extent of anthropogenic disturbance is a combination of etorphine HCl, medetomidine HCl and azaperone tartrate at a mean dose of 2.3±0.5mg, 3.3±0.8mg and 18.3±4mg respectively. This immobilization protocol is a third to be documented in Tanzania including lion (*Panthera leo*) immobilization protocol and African elephant (*Loxodonta africana*) immobilization protocol (Fyumagwa *et al, 2012;* Mpanduji *et al.,* 2012).

Although both protocols were adequate to immobilize impala in Serengeti National Park, the protocol consisting of etorphine HCl and xylazine HCl only could not immobilize impala in IGGRs and LGCA to desired effect. This observation suggests that there were differences in physiological status in SNP impala and those in IGGRs and LGCA (Table 3). Animals in Serengeti National Park are used to vehicles carrying photographic tourists and has minimum human activities, therefore, drug combination of 3-4mg etorphine hydrochloride and 10-30mg xylazine hydrochloride was enough to render immobilization corroborating with observations described by other workers elsewhere (Zeiler & Meyer, 2017). Although the combination of etorphine and xylazine induced immobilization in SNP, some impala showed elevated body temperature after induction (39.5°C) suggesting long period of high locomotor activity during induction (Meyer *et al.,* 2008). However, the use of second protocol with three drug combination of etorphine, medetomidine and azaperone had no such effect. A combination of etorphine HCl, medetomidine HCl and azaperone tartrate perfomed very well in IGGRs, where trophy hunting is practiced and in LGCA where trophy hunting, settlement, cultivation and livestock keeping are all unrestricted, suggesting that the later mounted a higher synergistic effect than the former.

Although the first protocol was applied in LGCA and IGGRs, it was very difficult to induce induction and recumbency at a reasonable time due to the fact that animals in the two protected areas are in areas with high human activities and persecution from trophy hunting and poaching. The observed immobilization effect between two drug combinations were not influenced by the body weight of the individual animals as impala in LGCA are heavier than those in SNP. The only explanation is that wild animals in LGCA and IGGRs are more stressed to an extent that with first drug combination a second dart was necessary to induce proper narcosis. This unpleasant experience made the operators to devise another drug combination to achieve desired narcosis with reduced induction time.

The second protocol with three drug combination when applied in SNP had rapid induction and shorter recumbency time than when applied in LGCA and IGGRs thus the second protocol was effective both in less disturbed and in areas with high anthropogenic disturbance. Another consideration for failure of etorphine and xylazine to induce rapid induction with reduced recumbency time in LGCA was the excitement of impala due to high interaction with livestock, cultivation and trophy hunting activities coupled with low synergistic effect of the two drug combination.

The immobilization using etorphine and xylazine provided slightly different physiological data as exhibited by unstable heart rates, high rectal temperatures and respiratory depression (Table 3) which necessitated the use of diprenorphine HCl and doxapram as antidote and respiratory stimulant respectively to stabilize the animals before further procedures were undertaken. Therefore, when using etorphine and xylazine combination, it is suggested that equipment for respiratory support be available as with any chemical immobilization procedure. However, impala captured using etorphine, medetomidine and azaperone combination provided a stable heart rates, rectal temperatures within acceptable ranges and adequate muscle relaxation which enabled subsequent collaring and sampling operations to proceed without high risk of losing the animal. Impala are very sensitive to etorphine HCl, therefore, even with the relatively safe protocol described here consisting of three drug combination, it is advisable to reverse the effect of etorphine immediately once the animal fells down and remain with the sedative and tranquilizer.

Diprenorphine HCl, yohimbine and atipamezole HCl were used as reversal drugs in both protocols administered slowly intravenously resulting in smoother recovery, with the animal coming on foot within 3min. However, one animal showed re-sedation when first protocol was used in the national park which was observed 30min later. The animal showed signs of standing still with the head down and lying down but with slight stimulation the animal responded by running-off and when left undisturbed reverted to sedation state again. This observation is probably due to re-narcotization from high dose of etorphine as described by other workers elsewhere ((Zeiler *et al.,* 2017).

CONCLUSION

Impala were successfully immobilized with both protocols consisting of either etorphine and xylazine combination inside Serengeti National Park or etorphine-medetomidine-azaperone in Loliondo Game Controlled Area (LGCA) and Ikorongo-Grumeti Game Reserves (IGGRs) but the later combination proved to be effective, reliable and safe. However, in animals with poor body conditions, the etorphine and xylazine combination quite often may require respiratory stimulants as recovery might be prolonged and might suffer from hypoxia.

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EVALUATING CONSERVATION AND DEVELOPMENT IMPACTS OF SERENGETI NATIONAL PARK

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ABSTRACT

National Parks often have multiple stated objectives to fulfill: protecting wildlife, providing safe and attractive tourist destinations, and supporting economic development of surrounding communities. With increasing threats to global biodiversity and limited budgets, parks are called on to justify the return on investment of their community development programs. The Serengeti ecosystem is surrounded by more than 120 villages, each of which views the costs and benefits of living near protected areas differently. Serengeti National Park (SENAPA) recently adopted a new benefit-sharing model: "The Serengeti Conservation Challenge," a competitive conservation and development program aimed at rewarding those villages adjacent to the Park that are contributing to the conservation of natural resources. In order to empirically assess the future impact of this program, a baseline evaluation was conducted on sample of 34 villages which are eligible to apply to SENAPA for development projects. Nine-hundred and ninety-six randomly selected households were interviewed between December 2016 and February 2017 using a community based participatory research approach. Local enumerators were trained to conduct structured household interviews in order to provide a baseline information against which to measure change in attitudes, perception and socio-economic status due to SENAPA investments. Preliminary results of regression analyses indicate that households held a widely positive view of SENAPA despite reporting personal costs incurred far outweighing benefits received. Neither village infrastructure projects nor loss of crops due to wildlife had a significant impact on attitudes toward conservation, however loss of livestock due to predation, while less common, significantly influenced attitudes toward the Park. We suggest that in addition to ensuring that benefit-sharing is more directly linked to conservation outcomes, certain types of interventions - specifically increasing off-farm opportunities through employment and entrepreneurship - likely result in the greatest potential return on investment in improving local attitudes toward conservation.

INTRODUCTION

The Greater Serengeti ecosystem encompasses roughly 30,000 square kilometers, comprised of a complex mosaic of land-use types and protected areas. The defining characteristic of the ecosystem is the migration of some two million wildebeest and other wildlife species(Sinclair *et al*. 2007; Hopcraft *et al*. 2015). Together with Ngorongoro Conservation Area (NCA), Serengeti National Park (SENAPA) is the premier tourist destination in Tanzania, a UNESCO world heritage site, Man and Biosphere Reserve, and was recently voted one of Africa's Seventh Natural Wonders. A multitude of governmental, private, and non-governmental organizations has promoted conservation in the Serengeti ecosystem for decades through both law enforcement and community-based conservation policies. The Serengeti ecosystem encompasses SENAPA at its core, game reserves (Grumeti, Ikorongo, Maswa and Kijereshi), Loliondo Game Controlled Area (LGCA), the Ngorongoro Conservation Area, and two (Ikona and Makao) community-run Wildlife Management Areas (Figure 1). The ecosystem also includes an estimated over 750,000 people, in over one hundred villages that interact with these areas and the natural resources therein(Rentsch and Packer 2015; Parks 2016; Kaltenborn *et al*. 2008). Despite its world-renowned natural and economic value, the ecosystem is currently facing unprecedented changes. Increasing pressure for development, tourism investment, evolving wildlife management efforts, climate change and human-induced land-use change are impacting this ecosystem in a myriad of ways. Unsustainable use of natural resources such as illegal hunting, overgrazing and deforestation may represent a serious threat to the health and functioning of the ecosystem. At the heart of this ecosystem are the local people who presently bear many of the costs while receiving few benefits of biodiversity conservation.

Since 1992, SENAPA has provided infrastructure development support to surrounding communities through its Support for Community Initiated Project (SCIP) programme. The goal of this programme is to ensure benefits from conservation are reaching communities. However, while this programme has delivered significant infrastructure development to local communities, the link and subsequent impact on conservation outcomes remains tenuous. Decisions on which village infrastructure projects to support are not based on participation in conservation actions, but in some cases projects have been prioritized to villages with highest numbers of arrested poachers, or reports of human-elephant conflict have been prioritized(Labora 2014).

Economic development within the ecosystem, particularly Serengeti and Ngorongoro Districts, is closely linked to the conservation and sustainable use of its natural resources (especially wildlife), as tourism is a major income generating activity (Damania and Scandizzo, 2017; Schmitt 2010). Consequently, a recent project implemented by SENAPA and Frankfurt Zoological Society with support from the German Cooperation aims to address both biodiversity conservation and the socio-economically sustainable development within the Serengeti Ecosystem. In order to adequately assess the impact of this project and the shift toward linking local benefits accrued from the National Park to conservation outcomes, extensive monitoring is required. First to evaluate the impact of the Park's community development investments, but also to measure whether these investments had a positive impact of conservation outcomes.

The "Serengeti Conservation for Development Challenge" was recently proposed as a way to improve the equitability and transparency of the allocation of benefits to communities from SENAPA. This is envisioned to be a competitive conservation and development program aimed at rewarding those communities (villages) adjacent to SENAPA that are committing themselves to conservation of natural resources for future generations. The Conservation Challenge is anticipated to consist of an open competition among villages for social infrastructure benefits from National Park, through which villages are rewarded forachieving conservation outcomes and innovative conservation solutions to ecosystem threats. Villages will submit an application to request support from SENAPA for social infrastructure projects identified by the village government. The request will then be reviewed and evaluated based on conservation and development criteria by a technical committee to ensure performance-based benefit sharing free of political interference. SENAPA and other stakeholder have identified the need for rigorous monitoring and evaluation to determine an equitable and transparent selection process, and to measure the impacts on key conservation indicators.

Baseline data was collected in order to detect changes on the target beneficiaries as a result of the project implementation. The baseline survey was designed to cover areas where key project components will be implemented, and where the SENAPAoutreach department operates. The goal was to assess and benchmark relevant starting points for project performance indicators, as well as assess the impact of the project and the National Park's Outreach Department on community livelihoods and attitudes toward protected areas. Here we present some findings of the baseline household survey, investigating factors which influence a household's views toward the National Park and willingness to participate in conservation activities. We use these data to identify potential ways in which SENAPA might improve attitudes and support for conservation, and highlight the need for more effort and continued long-term monitoring to measure impacts of SENAPA investments in community development on both local livelihoods and conservation indicators.

MATERIALS AND METHODS

Study Area

This study was conducted in the Greater Serengeti Ecosystem in Northern Tanzania, located between latitudes 2° and 4°South, and longitudes 33° and 35° East. Specifically, the study focused on households from villages surrounding SENAPA, in the Serengeti District of Mara Region and Loliondo Division of Ngorongoro District in Arusha Region. These areas were prioritized due to their long history of interaction with SENAPA's Outreach Programme, and their inclusion in the Serengeti Ecosystem Development and Conservation Project (SEDCP), which is intended to ensure equitable benefits to villages through the Support for Community Initiated Projects (SCIP).

Multiple methods were employed for the purpose of evaluating the impact of improving livelihoods and engaging communities in conservation by Serengeti National Park's Community Outreach Department. These included a household survey, compilation of data from District Council and Village Offices, and historical records kept by SENAPA. Household questionnaires were programmed into Open Data Kit (ODK) software using ODK's online Build tool, and downloaded onto Amazon Fire tablets to enable real-time data collection by local enumerators. Potential local enumerators were selected from each District included in the study, with the requirement that they must be residents of that District, and at least four enumerators be fluent in each of the most common local dialects. Ten to twelve enumerators were recruited in each District, and received extensive training by Frankfurt Zoological Society and SENAPA staff on the use of the data collection tools, ethical research guidelines, sampling techniques, and provided with scripts with which to introduce the study to each household. Extensive testing of the questionnaire was conducted at the conclusion of the training, and each participant was evaluated on their accuracy, timeliness and consistency of the data enumeration. Only the eight participants with the best performance during the testing in each District were offered contracts as enumerators in the study.

To be included in our possible sample, the villages had to be within the districts of Serengeti (to the Northwest) or Ngorongoro (to the East) and the village had to be eligible for conservation funds through the Tanzanian National Parks SCIP program. Each area had a total of 35 possible villages that met our sampling requirements. The survey was conducted in villages in the northwest and the northeast of the Serengeti ecosystem using a stratified random sampling protocol (Figure 1).

The survey area also included villages that were selected as part of a similar study in 2006/07, and any village surveyed in 2006 was automatically included in our sample for 2016/17. For villages that had subsequently sub-divided (common practice in Tanzania once villages become large) in the last decade we resampled the new village that retained the original village center from 2006/07. After determining which villages to resample from our 2006/07 study we randomly chose additional villages in each area to give us a total of 15 villages in Ngorongoro and 18 in Serengeti, or just over 40% and 50% of the possible villages sampled respectively (Figure 2).

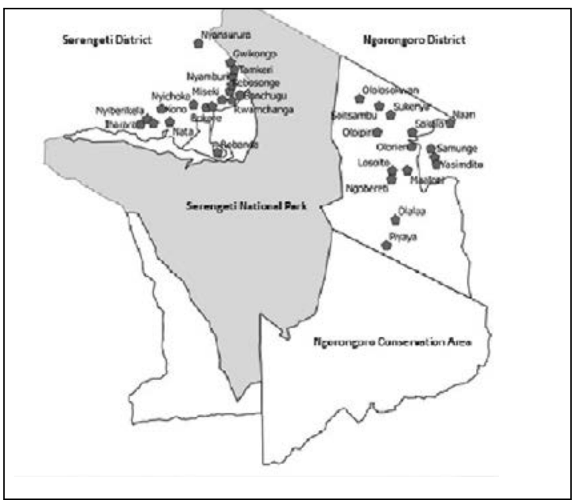

***Figure 1**. Villages surveyed*

Figure 2. *Percentage of households reported crop raiding increasing.*

enumerators always surveyed the sub-village containing the village center and randomly chose two of the villages' additional sub-villages, for a total of three sub-villages. If a village had three or fewer sub-villages, the enumerators interviewed households in every sub-village. Within each sub-village, the enumerators used the village roster to randomly choose 10 households (with a range of 9 to 15 actually surveyed), or when a roster was not available, they systematically sampled households in a randomly determined compass direction. This sampling coverage lead to between 29-35 households per village, with a median of 30 households per village and a total of 996 questionnaires. However, after removing missing data, 827 households had complete data available to be used for our analysis.The enumerators conducted each interview in Swahili, or the local language spoken by the respondent. At each household, the interviewer asked to speak with the household head. If unavailable, the field team interviewed someone else in the household over the age of 18 who was most knowledgeable about household affairs. The enumerators collected data from November 2016 through February 2017 using hand held tablets programmed with the ODK survey tool application for enumeration. Data were uploaded once per week and stored in a secure platform. Data was reviewed weekly and any discrepancies or irregularities in the data were communicated back to the enumerators for clarification, and to provide feedback in order to improve enumeration.

The household survey included questions about demographics, assets and ownership, livelihoods, access to natural resources, human wildlife interactions, attitudes about Serengeti, and the benefits and problems associated with Serengeti. The survey also asked about village perceptions toward conservation and specifically focused on perceived benefits and costs emanating from SENAPA. Respondents were not prompted about possible benefits and costs, and were given the option mentioning multiple responses in order not to bias their responses. The enumerators then assigned the responses to a list of predetermined options, with an option of recording the response directly in an "other" category. The enumerators also asked about wildlife interactions, village land use plans and conservation responsibilities. These questions were not prompted and households could list as many as desired.

Due to our sampling design, our data are stratified in the two Districts (Serengeti and Ngorongoro) and clustered within village and within sub-village. Because villages have different population sizes and areas have different numbers of villages, sampling weights were used for each household to more accurately assess population averages. The clustering and stratification affect the standard errors, and the weighting of data affects point estimates as compared to an assumption of a simple random sample. Accounting for these deviations from simplified random sampling prevents falsely rejecting the null hypothesis because of the non-random sampling design.

Villages were sampled independently in each stratum to improve the efficiency of the statistical design. Stratification will yield greater precision and thus smaller standard errors than a simple random sample when the strata variable and variable of interest are closely related. The clustered nature of choosing households from within sub-villages from within villages suggests there is likely to be correlation among household responses. The correlation is likely to be stronger between two households who reside in the same village than across different villages, and stronger still within a sub-village. The correlation increases the standard errors relative to a simple random sample. Consequently, assuming a simple random sample will understate the standard errors.

Data was analyzed using STATA v 15.1, and maps produced using QGIS 2.16.3 with GRASS 7.0.4.

RESULTS

One of the key indicators of interest for the SENAPA community outreach programme is measuring whether there is any change in employment by local communities in the sectors of wildlife management, conservation and tourism over time (Table 3). In order to capture the demographic impacts of employment, this study utilized multiple questions aimed at capturing these impacts. For Serengeti and Ngorongoro Districts, 23% and 10% of households respectively reported off-farm employment and of these, only 4% and 2% of households reported off-farm employment related to wildlife industries (including tourism and conservation).

The SENAPA Community Outreach Programme regularly visits adjacent villages to discuss conservation issues, development needs, provide environment education programs and share information about the Park. The baseline survey asked about how households receive information from the park. Just over half of respondents reported actually receiving information about SENAPA in some form. The percentages were similar for both districts with 54% and 53% for Serengeti and Ngorongoro Districts respectively. The most common form of receiving information was via village meetings with park staff (Figure 2).

Community based conservation initiatives around SENAPA have aimed to provide benefits to the local people for over two decades. The proportion of respondent reporting benefits received from the National PArk are shown in Figure 4 while “No Benefit” was by far the most common response (81% Serengeti District, N=540; 90% Ngorongoro District, N=456), village infrastructure was the most commonly mentioned benefit received (11% Serengeti District and 9% Ngorongoro District). The survey indicates that conflict with wildlife was reported by the majority of households (Table 5). Households indicating that the conflict with wildlife is increasing are shown in Figures 3 and 4. Crop damage was the most mentioned form of wildlife conflict in the Serengeti District (Figure 3) while in the Ngorongoro District livestock depredation was the most reported (Figure 4).

Table 3: Percentages of households with members who have emigrated from the village due to employment

District	Households engaged in off-farm employment	Working in wildlife sector	Left village for employment elsewhere	Of those who left, how many are working in wildlife industries
Serengeti	47%	12%	28%	7%
Ngorongoro	28%	13%	14%	3%
Both Districts	41%	12%	22%	5%

Table 4: Benefits households receive from Serengeti National Park. (Serengeti District, N=540; Ngorongoro District, N=456)

Benefits	Serengeti Dist.	Ngorongoro Dist.
None	81%	90%
Money	2%	0%
Village buildings	11%	9%
Maintenance of village buildings	<1%	0%
Employment	5%	0%
Income generating activities	2%	<1%
Pest animal assistance	<1%	<1%
Natural resource use	<1%	0%
Conservation / ecological service	<1%	0%
Market access (i.e. village supply to a market)	0%	0%
Food (non-bushmeat)	0%	0%
Car transport	0%	<1%
Conservation education	<1%	<1%
Purchases in village (by park officials, tourists, etc.)	<1%	0%
Tourism	1%	<1%
Disease control / prevention	0%	0%
Do not know	<1%	0%
Other	<1%	0%

The Serengeti General Management Plan specifies targets for the Community Outreach Programme aimed at improving attitudes toward the Park by local communities. In this study, respondents were asked to rate how they would feel if SENAPA no longer existed (Figure 5 and 6). Sixty-four percent (64%) of respondents overall reported a positive attitude toward SENAPA (reporting that they would feel "sad" if the park no longer existed).

In Ngorongoro District, half of respondents (51%) had a positive attitude. Thirty percent (30%) of Ngorongoro District respondents had a negative attitude (reporting they would feel “happy” if the Park did not exist), while 19% were indifferent. However, 76% had a positive attitude in Serengeti District, with only 7% indifferent and 17% negative. These largely positive attitudes were reported, despite only 16% of respondents reported receiving a benefit (of any kind) from SENAPA; with 19% of Serengeti District.

Respondents reporting a benefit compared to 12% in Ngorongoro District. Despite the lack of benefits and only half of respondents having a positive attitude toward SENAPA, 70% of respondents in Ngorongoro District reported feeling like a partner in conservation. This was higher than the 63% reporting the same feeling from Serengeti District. Overall there were a remarkably high percent of respondents feeling like a partner in conservation (66%), with about a quarter not feeling that way (24%) and 10% unsure.

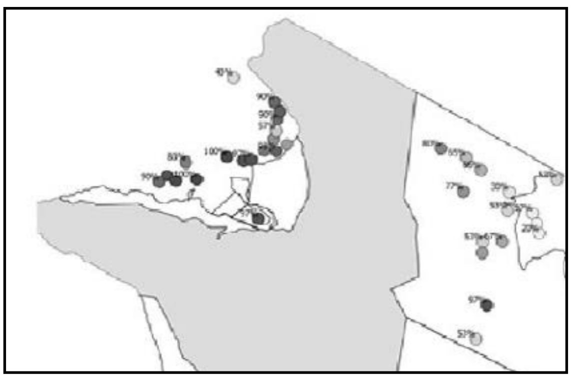

Figure 3. *Percentage of households reported depredation increasing.*

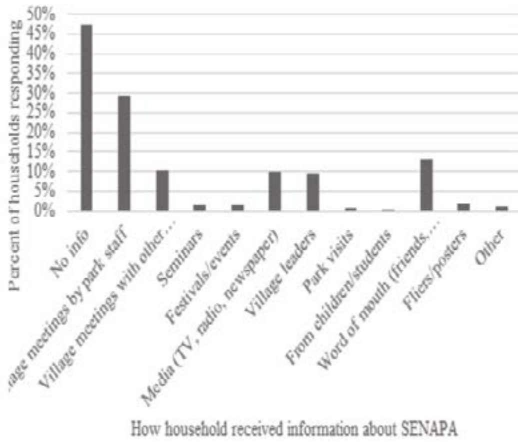

Fig 4: Responses to how households receive info about Serengeti National Park (if received info)

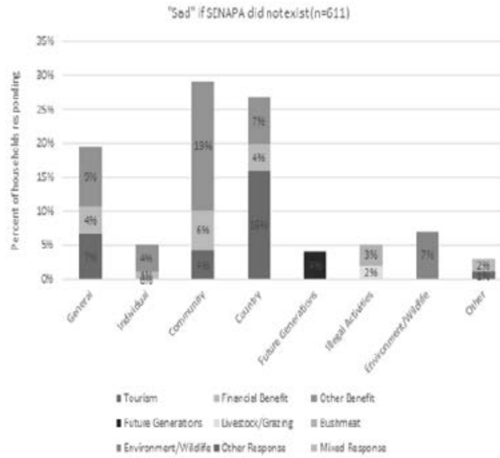

Fig 5: Reasons given for being "sad" if park were not there

To better understand what factors may be influencing the attitudes reported toward SENAPA (whether a household reported they would be “Happy”, “Sad” or “Indifferent” if the Park no longer existed), an ordinal logistic regression model was built with households’ reported attitude toward SENAPA as the dependent variable and a number of measurable indicators as independent variables. The independent variables were selected from among those that were hypothesized to potentially impact attitudes, and would be potentially impacted by the SENAPA project interventions. The following indicators were included in the regression model as independent variables in Table 6.

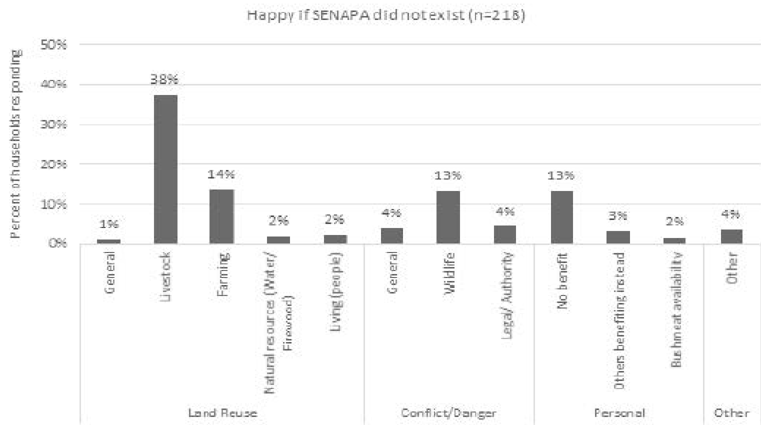

Fig 6: reasons given for being "Happy" if park were not there)

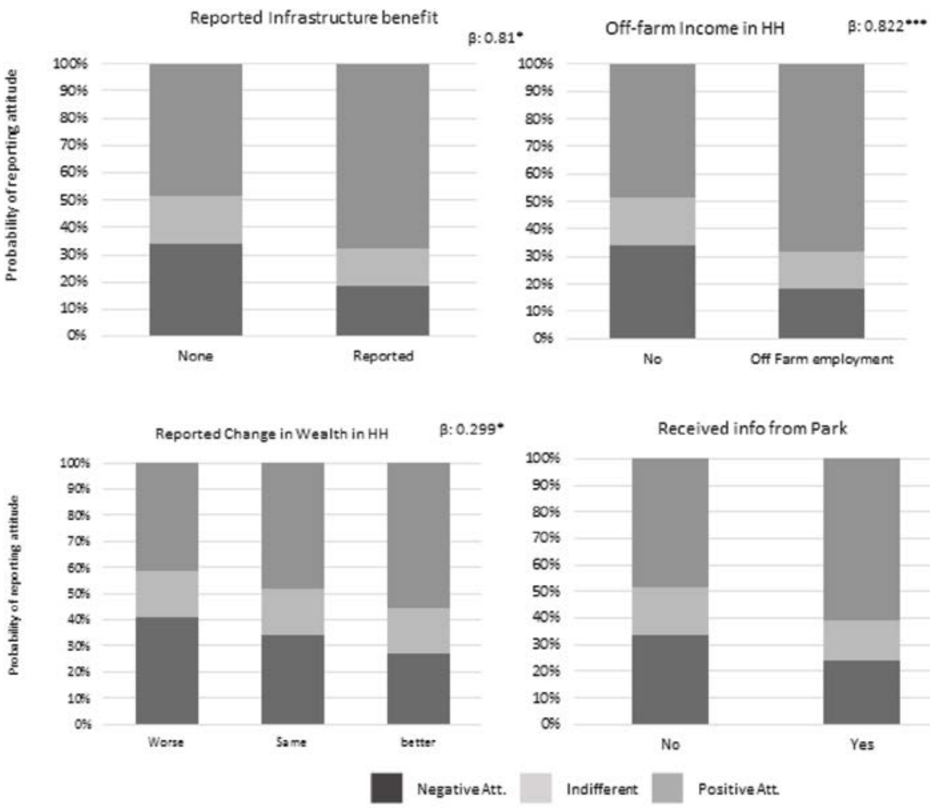

Fig 7: Influence of key variable on the probability of a household reporting a positive, negative or neutral view toward SENAPA

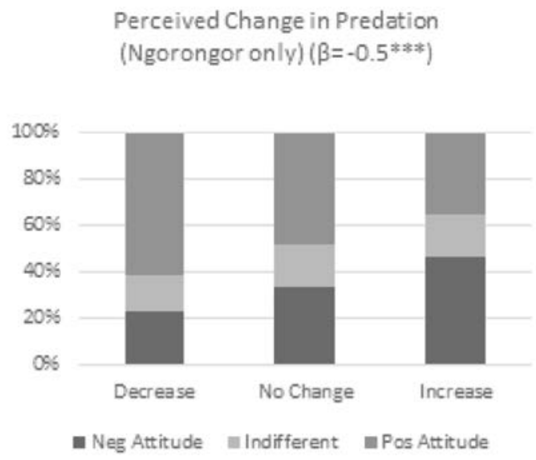

Fig 8: Probability of household holding a positive attitude toward SENAPA decreases as household reports predation increases.

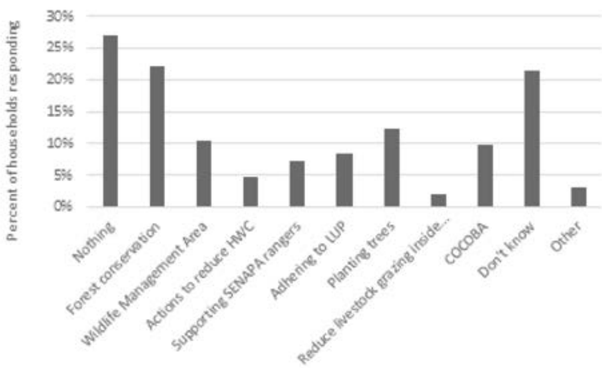

Fig 9: Responses to what respondents believe their villages is doing to support conservation

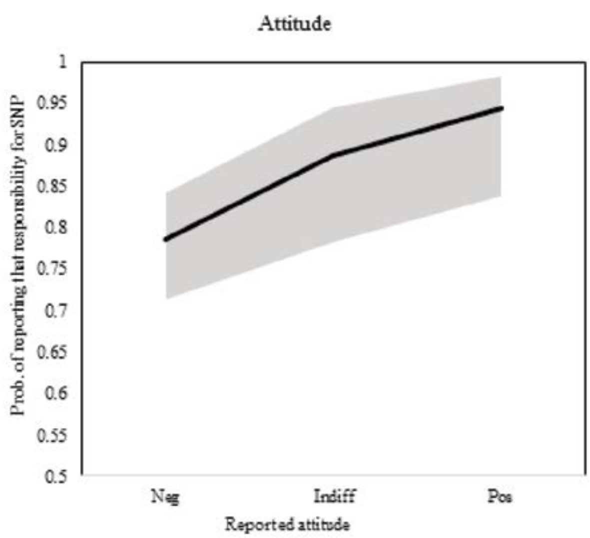

Fig 10: Probability of respondent reporting that they have a responsibility to contribute to the conservation of SENAPA, depending on their reported attitude toward SNP. Dark grey line = probability by response. Light grey area = 95% confidence interval

Table 5: Human-wildlife conflict

District	Conflict type	Responses
Serengeti	Crop damage	53%
	Livestock depredation	40%
Ngorongoro	Crop damage	24%
	Livestock depredation	72%

For those variables which were found to be significant (Table 6), the probability of their influencing a household's attitude toward SENAPA are presented in Figures 7, 8 and Figure 9. The probability of a household having a positive attitude toward the park increased if a household reported infrastructure as a benefit from the Park, even if that benefit was accrued at the village, not necessarily the household (β =0.81, p=0.031). Members of the household with off-farm income were also significantly more likely to hold a positive view toward SENAPA (β =0.822, p=0.004). Those households which self-reported a positive change in their perception of their wealth over the past five years had an effect (β =0.299, p=0.046). Households responding that they regularly receive information about the park were also more likely to hold positive views toward SENAPA (β=0.493, p=0.005).

Variables of households reporting loss of crops to wildlife and loss of livestock to wildlife were included in this logistic regression model as an interaction term with the District. However, only households reporting loss of livestock to wildlife was significant in influencing the probability of those households holding more negative attitudes toward SENAPA (Table 6).

Table 6: Variables included in Ordinal Logistic Regression

Variable name	Possible Responses	B coefficient	p-value
Dependent Variable:			
Reported attitude toward SENAPA	Positive, negative, neutral, no answer, don't know		
Independent Variables:			
District effect	Serengeti, Ngorongoro	0.976	0.005***
Gender effect	Male, Female	-0.290	0.081
Perceived wealth change	Better, same, worse, no answer	0.299	0.046*
Report infrastructure benefit	Yes/No	0.810	0.031*
Receive info about park	Yes/No	0.493	0.005***
Report costs from SENAPA (non HWC)	Yes/No	-0.747	0.005***
Off farm employment	Yes/No	0.822	0.004***
Born in village	Yes/No	0.228	0.327
Change in crop damage (perceived)	Increase, decrease, no change, don't know	-0.173	0.174
Change in predation (perceived)	Increase, decrease, no change, don't know	-0.529	0.001***
District # perceived change crop damage	Interaction term	-0.310	0.878
District # perceived change in predation	Interaction term	0.618	0.003***

Despite the relatively low reported benefits and presence of crop damage and livestock depredation, in Serengeti District 69% of households report their village is contributing to conservation and 84% report believing their village has the responsibility to conserve SENAPA. For Ngorongoro District, 78% of households report their village is contributing to conservation and 80% report believing their village has the responsibility to conserve SENAPA. There was, however, a variety of ideas as to how villages were aiding in conservation (Figure 9). Households reporting a positive attitude toward SENAPA were also significantly more likely to respond that they have a responsibility for contributing toward the conservation of the Park (Figure 10).

DISCUSSION

The results presented here provide a snapshot as to the status of a number of indicators at the start of the “Serengeti Challenge” intervention through the current SENAPA initiative. The survey developed for this study was designed to generate a baseline against which to measure potential changes in household socio-economic status and attitudes toward SENAPAas a result of development investments by the Park which some of these villages are expected to receive in the coming years. However, these data also provide important insight into what is currently influencing attitudes toward the Park by neighboring communities, and which can assist SENAPA to target the intervention more directly to improve the chance of having a positive impact on attitudes toward protected areas and conservation.

The Serengeti General Management Plan (2016) states that among the targets of the Outreach Programme is: “Improvement and maintenance of relationship with neighbouring communities and other key stakeholders.” The results of the ordinal logistic regression help to shed some light on some of the factors which may be influencing the probability of a household holding favorable views toward the National Park (Figure 7 & 8). Off-farm income, regardless of whether or not the source of the income was linked with conservation or tourism, had a highly significant influence of households holding favorable attitudes toward the National Park. While at this stage we cannot infer the mechanism of this influence, we conjecture that households with off-farm income are likely less reliant on crops and livestock, which are susceptible to loss by wildlife.

However, off-farm employment was still relatively uncommon in the study area, with livestock keeping and agriculture comprising the primary livelihoods by a wide margin. Local off-farm employment can be a form of direct benefit to households, andseeking employment elsewhere can also lead to emigration from the village. It was therefore important to identify whether benefits accrued from proximity to the National Park such as wildlife-based employment, which could be a “pull” factor for immigration or discourage emigration. Alternatively, employed household members based elsewhere may contribute to the household through remittances, but not be counted as current household members. Interestingly, almost a quarter of respondents said that a household member left the village because of employment elsewhere (Table 3). This percentage jumps to 41% when looking at just those households who report being engaged in off-farm employment. While the data does not have the granularity to determine if those household members engaged in off-farm employment were in fact the same ones who left the village, the correlation suggests off-farm employment and emigration are connected.

While the majority of households in the sample did not report any benefits received from the National Park, and in fact reported costs incurred from human-wildlife conflict, the surprising result was that most also reported that they would not be happy if the Serengeti National Park were no longer there (Figure 6), the responses differed by District and village. For those that reported negative feelings toward SENAPA ("Happy" if the park were no longer there), the primary reasons given were conflict over land-use, where they see the Park as restricting access to additional land for grazing or agriculture (Figure 6).

The results indicate that while the majority of the sample reported a positive view towards SENAPA (Figure 5), there were a number of variables that significantly predicted the likelihood of a household holding a positive view toward the Park shows the probability of a household's view toward the park based on their response to several significant variables. While reporting benefits from SENAPA in the form of village infrastructure projects, and a reported improvement in household overall wealth over the past five years did significantly increase the probability of a positive view toward the Park, having a household member engaged in off-farm income generating activities, or reporting regular information received about the park were highly significant.

The results of the regression (Table 6) also suggest that households which reported receiving information about SENAPA were significantly more likely to hold positive attitudes towards the Park. To reach these communities, the SENAPA Outreach Programme regularly facilitates meetings with local villages, education programs, and supports income-generation training programs. However, with limited staff and budget and over 100 villages immediately adjacent to protected areas in the Greater Serengeti Ecosystem, only a small fraction of village meetings are held annually. Additionally, village meetings may not be the more efficient way to share information with households within these adjacent villages. The results presented in Figure 3 help identify the methods which households most frequently receive information about the park, and the proportion of respondents mentioning each. This baseline is not only helpful in detecting changes over time, but also in highlighting which methods reach the most households.

When compared to the annual expenditure recorded in the Outreach Programme budget reports, each method can then be evaluated on its cost-effectiveness. Conflict with wildlife is often one of the major costs of living near protected areas(Blackburn et al. 2016; Fernando et al. 2005; Lamarque et al. 2009; Hoare 2012), and as expected, both crop damage and predation were prevalent in the responses. Crop damage in particular was reported to be increasing throughout the study area, and particularly in the Serengeti District. Much of the crop damage is attributed the large elephant population in the Serengeti ecosystem, which was found to be increasing significantly in recent years (Morrison et al. 2017; Chase et al. 2016).

Villages in the two Districts included in the study differed in both the wildlife ecology and livelihoods, which can influence the type of conflict with wildlife and potential costs incurred. In Serengeti District, sampled villages were largely agropastoralist. The abundant agriculture and proximity to the adjacent Game Reserves and the Grumeti River make this area a hotspot for crop destruction by a growing elephant population within the ecosystem (Estes et al. 2012; Hoare 2012; Jafari R. Kideghesho 2008). Villages to the East of the National Park in Loliondo Division of Ngorongoro District are predominantly Maasai communities whose primarily livelihoods remains based on pastoralism, although agropastoralists from the Sonjo tribe are also found in this area, and recent trends suggest that agriculture is becoming more common even among pastoralists. (Mccabe, Leslie, and DeLuca 2011; J. R. Kideghesho 2008; Schmitt 2010). Loss of livestock through predation by wildlife is therefore a more common cost from proximity to the National Park for communities in Ngorongoro District (Ikanda and Packer 2008; Franco et al. 2018).

Interestingly, whether households reported an increase or decrease in crop damage due to wildlife did not have a significant impact on their attitudes toward the Park, regardless of district. This was surprising given that human-elephant conflict has been reported to be increasing in recent years, especially in Serengeti District where agriculture is still the predominant livelihood. However, loss of livestock due to predation (Figure 7), while less common, significantly influenced attitudes toward the Park for those living in Ngorongorowhen District was included as an interaction term. This suggests that human-wildlife conflict, while more common in Serengeti District, was more likely to influence a household's attitude toward SENAPA in Ngorongoro District.

Perhaps this is due in part to the livelihood strategies employed in these two Districts. While the East is predominately Maasai pastoralists, the agropastoralist communities to the West actually have higher densities of livestock, since the Maasai have historically maintained larger pasture to allow transhumant pastoralism. At the same time, a shift toward agriculture means that there is more farming on the East than in the past(Mccabe, Leslie, and DeLuca 2011). Both Districts have similar densities of elephant populations, and presumably could face similar encounter rates with elephants, except that the density of agriculture, and thus risk of crop raiding, in Serengeti District is much higher. Since much of the available grazing land in Serengeti District isalready occupied, there is little room for livestock numbers or predation to increase. Not so to the East, where it may be thatincreasing livestock close to the boundary of the Park has led to an increase in reported predation events. While we cannot conclusively point to the mechanism to explain this phenomenon, understanding that the perception of increasing livestock predation in Ngorongoro District influences attitudes toward the National Park is useful as it helps to identify where the SENAPA Outreach Program can have an impact on improving attitudes through benefit sharing, and where they cannot.

Overall, these results suggest that in addition to ensuring that benefit-sharing is more directly linked to conservation outcomes, certain types of interventions - specifically increasing off-farm opportunities through employment and entrepreneurship - likely result in the greatest potential return on investment to SENAPA if the goal is to improve local attitudes toward conservation. While the focus of this analysis was largely on the factors influencing reported attitudes toward SENAPA and willingness to engage in conservation activities, we acknowledge that there is a dearth of evidence as to whether these attitudes translate into conservation actions and outcomes. Evaluating whether the investment in community infrastructure or outreach results in conservation benefits will require a much longer scope to the study.

The results of this baseline survey provide a foundation for SENAPA to be able to evaluate the impact of their shift toward a more transparent and equitable benefit-sharing scheme, to be piloted in the coming years. However, as SENAPA is expecting to scale up the level of investment in benefit sharing with villages within the study area over the next three to four years, we anticipate that a subset of the sampled villages will be recipients of these development projects. By regularly resampling these villages using this standardized methodology, SENAPA will be able to detect changes in target indicators over time, and compare those from villages receiving benefits to those that have not received the same benefits. The indicators which should be regularly monitoring to evaluate this program include: incidences of illegal activities detected, while controlling for law enforcement effort; numbers of key wildlife species based on censuses; the results of the aerial livestock census; and the status of land-use detected remotely. Linking these indicators with the Park's level of investment in community engagement and socio-economic development programs in the same villages, will help provide stronger evidence for or against the link between SENAPA's community engagement efforts, their impact on community development metrics, and local participation toward achieving conservation outcomes. Improving understanding of the conservation and development impacts of the Park's Outreach Programme can assist the National Park in directing their community engagement efforts more efficiently.

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MONITORING HUMAN-WILDLIFE CONFLICT IN THE WESTERN SERENGETI

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ABSTRACT

In the western Serengeti, Human-Wildlife Conflict (HWC) has become an issue of high priority – due to increasing numbers of people and wildlife and high rates of land conversion. HWC is a source of frustration for community members and protected area managers. An understanding of the extent and severity of conflict incidents is required in order to develop appropriate and effective strategies for mitigation. Here we present an update on two research and monitoring efforts in villages proximate to the Ikorongo and Grumeti Game Reserves and Ikona Wildlife Management Area, and their relevance to mitigation. We used household surveys for two projects – first, to continuously monitor conflict incidents in ten villages, and second, to examine the extent of different forms of conflict experienced by households within 12km of the reserve boundary. Results from both surveys indicate that crop damage is the most common form of conflict, and elephants are the most common perpetrator, with damage being widely dispersed. Among households with livestock, loss to depredation by hyena was most common and widespread, while losses due to elephant, lion, and leopard are rare and localized. Due to its widespread and severe nature, in the western Serengeti Human-Elephant Conflict mitigation should be of the highest priority. The spatial extent of vulnerable areas also indicates that strategies must be applied across the landscape, and incorporate both localized, field level deterrents and broader, coordinated approaches. Alternatively, more geographically focused strategies can be implemented to reduce Human-Carnivore Conflict.

Key-words: Human-wildlife conflict, Serengeti, elephant, lion, hyena

INTRODUCTION

Human-wildlife conflict (HWC) develops due to competition for space and resources, and negatively impacts both people and wildlife (Madden, 2004). HWC is considered a primary threat to many species of conservation concern, and is associated with negative attitudes towards conservation efforts, increased support for the use of lethal control, and the occurrence of retaliatory killings (Woodroffe, 2005; Treves *et al*., 2006; Holmern *et al.*, 2007; Kissui, 2008; Hemson *et al*., 2009). Conflict affects people via damage to crops, livestock, structures, and other property, and in the most severe cases, causes injury and death. HWC escalates when people who experience the consequences of living in close proximity to wildlife are unable to adequately address or mitigate the conflict, or feel that the requirements or presence of wildlife are prioritized over their own livelihoods (Madden, 2004). This escalation is particularly notable in areas relying on subsistence economies, as damage has the potential to contribute to household insecurity (Scoones, 1992; Naughton-Treves, 1997; Wang & Macdonald, 2006; Holmern *et al.*, 2007; Kaswamila *et al.*, 2007).

In the western Serengeti of Tanzania, communities are isolated and bordered by a number of protected areas that primarily prohibit extractive uses and contain large numbers of wildlife, particularly elephant. Since 2003, managers have recorded a tenfold increase in buffalo, sixfold increase in lions, and more than threefold increase in elephant populations (Goodman &Mbise, 2016). During this time period, crop and livestock losses to wildlife have become significant issues in villages that neighbor the reserve, and are a source of increased tension between community members, government officials, and protected area managers (Walpole, 2004; Personal observations, NM).

Previous research in the western Serengeti examining relationships between conflict and conservation attitudes has highlighted the importance of addressing HWC locally (Kaltenborn *et al*., 2006a; Kaltenborn *et al.* 2006b; Holmern *et al*., 2007; Kideghesho, 2007). In general, findings indicate the local attitudes towards protected areas are negative (Kideghesho, 2007), and that depredation on livestock by carnivores is associated with increased support for the retaliatory killing of wildlife (Holmern *et al*., 2007). Other work has examined the prevalence of livestock losses to predators in select villages(Holmern *et al*., 2007; Holmern & Roskaft, 2013), and using village-aggregated historical reports to examine the spatial and temporal aspects of crop and livestock losses (Snyder, 2016).

In order to develop efficient mitigation strategies for reducing conflict, it is important to allocate limited resources appropriately. An important first step is obtaining a thorough understanding of the extent and severity of different forms of conflict in order to define management priorities. Previous work has laid the foundation for our current understanding of HWC in the western Serengeti, but there are noticeable gaps in our knowledge. Primarily, the extent of HWC across the western Serengeti is unclear - household surveys tend to focus on a select number of villages, and village-aggregated records obfuscate trends. Self-reported losses make it difficult to evaluate severity of losses since they cannot be verified. Similarly, historical reports submitted to local authorities, although verified, collect limited information and have been demonstrated previously to inflate losses (Walpole, 2004). Here, we present initial findings from two household surveys designed to address these gaps in our knowledge on conflict extent and severity, and ultimately to produce an improved baseline that can be used to prioritize management actions and assist in identifying appropriate strategies.

MATERIALS AND METHODS

Study area

The study area is located in northern Tanzania (1°45' – 2°10' S, 33°50' – 34°50' E), adjacent to a suite of protected areas forming the western corridor of the Greater Serengeti Ecosystem(Fig. 1). This reserve complex provides habitat for a variety of threatened species (cheetah, elephant, leopard, lion, wild dog), large numbers of herbivores, and maintains a corridor that is used extensively by wildebeest, zebra, and gazelle during their seasonal migration. Between 2003 and 2016, wildlife populations in this area have increased substantially.

The people living in this area come from a variety of ethnic backgrounds, but are primarily of Bantu descent. The area is fairly isolated from urban centers and large markets. Subsistence agricultural activities are the most important source of income in both Bunda and Serengeti Districts. Nearly all households engage in farming, while around three-quarters of households raise livestock (NBS, 2012; Grumeti Fund, 2016). Along much of the reserve edge, settlements and farms are established immediately up to the reserve boundary. Community members have reported associating few benefits with living in close proximity to the protected area, and face the additional burden of incurring losses to wildlife (Walpole, 2004; Kideghesho & Mtuni, 2008; Grumeti Fund, 2016).

Data collection

Two surveys were used to collect information on the extent and severity of damage due to wildlife in the study area. All surveys were conducted by local enumerators trained in survey techniques, in Kiswahili, with the male or female head of household (or in their absence, another adult of 18 years or older was asked to provide responses), and at the respondent's home or farm.

The first survey emphasized understanding the extent of damage due to wildlife in communities proximate to the reserve boundary (< 12 km), and how this varies by wildlife species and conflict type. Systematic sampling was used in order to cover the entire study area. A data sampling grid composed of 3 km^2 cells and sampled one household per grid cell. This cell size was identified as the most appropriate scale due to tradeoffs between creating a fine-scale sampling frame, sampling effort, and ensuring that multiple households were contained within a single cell in rural areas. Grid cells that were inaccessible and those that did not contain settlements were used.

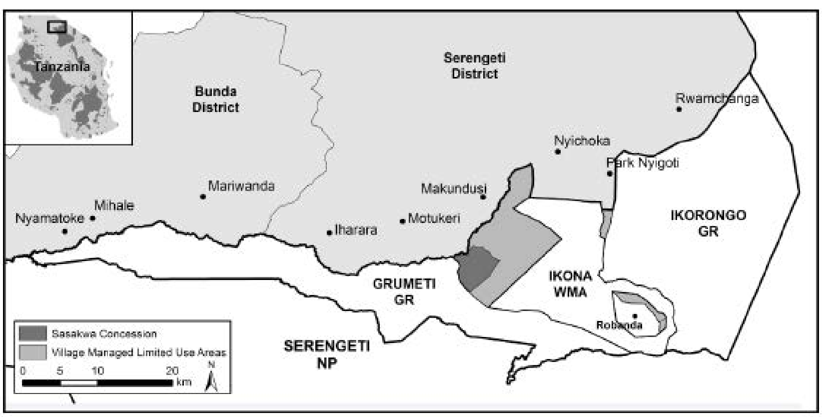

Figure 1: *Map of the western corridor of the Serengeti Ecosystem indicating the Ikorongo and Grumeti GRs, Ikona WMA Serengeti NP and various villages where HWCs are identified.*

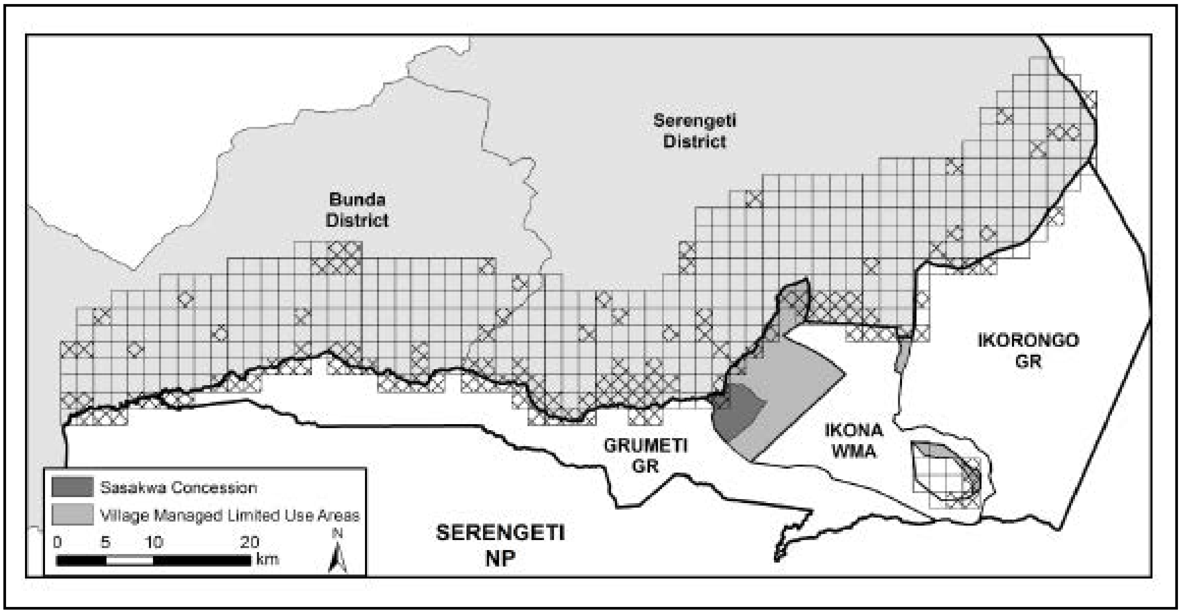

Figure 2: *Map of the sampling schema used in the systematic survey; in total, 419 households were sampled (one per grid cell). Uninhabited and inaccessible cells are those with hash marks. All sampled households are within 12 km of the reserve boundary.*

Respondents were asked only about damage incidents and agricultural practices in 2016, as expected extending beyond this time frame would be unreliable. Losses due to mammals were evaluated; respondents were provided with photos and names of wildlife species to aid accurate identification. Analysis only considers livestock damage with reference to cattle, dogs, donkeys, goats, and sheep. Responses about medium and large livestock types are expected to be accurate because these livestock are valuable and culturally significant, making losses memorable. In order to evaluate reporting rates, respondents asked to indicate how often they reported damage to local authorities for species that caused damage and are listed under the Dangerous Animals Consolations Regulations (MNRT, 2011).

To obtain basic measures of household security, respondents were asked to provide estimates of how often they experienced uncertainty that the household food supply would be enough to meet basic needs, and how often they sold possessions they would otherwise like to keep in order to support their households.

The second survey collected data on incident characteristics when the damage was still observable with the purpose of understanding the severity of damage experienced at the household level. Data was collected for a one-year period between October 2016 and September 2017. Due to time constraints and other limitations, we expected that people would be less willing to participate if they had to complete conflict reports with multiple people and at different times. As there are already governmental procedures in place to report damage in order to receive consolation payments, the existing reporting network was used. Training to Village Agricultural Officers (VAO) in ten villages bordering the reserve to collect additional data on damage incidents was done. To increase awareness of the project, additional village and ward officials also attended training. When responding to damage incidents, the VAOs would offer reporting head of households the opportunity to participate in the survey.

Consolation payments are only distributed for damage resulting from a specified list of dangerous animals –black rhinoceros (*Diceros bicornis*, N/A in study area), spotted hyena (*Crocuta crocuta*), hippopotamus (*Hippopotamus amphibius*), Nile crocodile (*Crocodylus niloticus*), buffalo (*Syncerus caffer*), lion (*Panthera leo*), and African elephant (*Loxodonta africana*) (MNRT, 2011). As expected reports only of these species through this reporting channel were received, the survey did not consider any other wildlife species. Enumerators visited the site of wildlife damage, evaluated the severity of the damage, and recorded information on agricultural practices. Crop damage was evaluated on a per-crop basis, and VAOs estimated the percentage of the crop lost based on pre-defined intervals (0-10%, 10-25%, 25-50%, 50-75%, 75-90%, 90-100%). Plots of mixed vegetables (> 2 types) were evaluated as a single variety in order to simplify field-level evaluations of damage severity. VAOs also quantified the number of livestock damaged, distinguishing between those injured and killed of each livestock type.

Responses were aggregated and evaluated using the statistical program R (R Core Team, 2017).

RESULTS

Damage extent

Respondents were 39 years old on average (range 18-88 years), and 50.6% were female and 49.4% male. Most of those surveyed (79.5%) were born locally, in either Bunda or Serengeti Districts. The average household size was eight people, and ranged from two to 28. The majority (63%) of sampled households report that during 2016 they experienced uncertainty about their household food supplies ‘often’ or ‘always’, while 85.9% reported selling possessions they otherwise would not wish to in order to bridge gaps in household income. Nearly everyone surveyed farms crops (99%) and raises livestock (74%).

The average farm size was six acres (range: 1-70). Respondents planted crops nine months out of the year (range: 2-12) and three crops (range: 1-10) on average. Respondents employed multiple strategies to prevent or deter wildlife from damaging crops (x = 2, range= 1-4), the most common being: shouting (72%), guarding (67%), chasing (23%), and fire (22%). The majority (60%) of respondents indicated that damage due to wildlife, rather than disease, weather, depleted soils, or labor, was the greatest threat to crop production. A high percentage of farming households (81%) indicated that they suffered crop losses to wildlife in 2016, with elephants being the most commonly identified species (Table 1).

On average, households owned 78 medium or large livestock (range: 1-764). Average composition consisted of 36 cattle (0-400), 23 sheep (0-300), 13 goats (0-100), three dogs (0-11), and less than one donkey (0-9). Almost all respondents reported guarding livestock (95%) during the day, and containing livestock (96%) and using dogs for guarding (66%) at night. Only 3% of respondents identified losses to wildlife as the greatest threat to livestock; instead, low productivity (59%) was the most common response, followed by the availability of grazing land (19%) and weather (15%). Roughly half of households owning livestock experienced losses due to wildlife in 2016, with most of these being due to hyena while losses to elephant, lion, and leopard were rare (Table 2).

Table 1. Crop damage characteristics resulting from a systematic survey of households within 12km of the reserve boundary.

Characteristics	Details	Responses
Farming households	Total	413 (99%)
Crop damage households (%)	Of farming households	81%
Households impacted by species	Elephant	79%
	Monkey	10%
	Baboon	9%
	Bushpig	2%
	Hippopotamus	1%
	Buffalo	< 1%
	Porcupine	< 1%
	Wildebeest	< 1%
	Mongoose	< 1%
Reporting elephant damage to VAO	Always (100%)	19%
	Often (75%)	43%
	Sometimes (50%)	19%
	Rarely (25%)	13%
	Never (0%)	6%
Elephant-crop damage estimated reporting rate		64%

Reporting rates of buffalo not included because of low number of occurrences of those who experienced damage. The elephant crop damage reporting rate is estimated based on the interval responses of how likely a household was to report damage to local authorities for consolation payments.

Respondents indicated that their likelihood to report losses to local authorities varied by wildlife species. People who experienced losses were most likely to report crop damage by elephant, and least likely to report livestock losses to hyena.

Damage severity

In total, 529 reports of damage by wildlife were verified by VAOs in ten villages. Damage by elephant was reported most commonly (91%), followed by lion (6%), hyena (2%), baboon (<1%), and buffalo (<1%).

Table 2. Livestock damage characteristics resulting from a systematic survey of households within 12km of the reserve boundary.

Characteristics	Details	Responses
Herding households	Total	312 (74%)
Livestock damage households (%)	Of herding households	53%
Households impacted by species	Hyena	52%
	Lion	8%
	Elephant	3%
	Leopard	3%
Reporting hyena damage to VAO	Always (100%)	3%
	Often (75%)	12%
	Sometimes (50%)	6%
	Rarely (25%)	29%
	Never (0%)	50%
Hyena-livestock damage estimated reporting rate		22%
Reporting lion damage to VAO	Always (100%)	21%
	Often (75%)	33%
	Sometimes (50%)	4%
	Rarely (25%)	21%
	Never (0%)	21%
Lion-livestock damage estimated reporting rate		53%

Reporting rates of elephant and leopard not included because of low number of occurrences of those who experienced damage. The hyena and lion livestock damage reporting rates are estimated based on the interval responses of how likely a household was to report damage to local authorities for consolation payments.

On average, respondents were actively cultivating 2 acres at the time of damage. Elephants were estimated to damage between 0.73 and 1.1 acres per report at the household level. Twenty varieties of crops were damaged, with the most commonly reported being maize, cassava, millet, and cotton (Table 3). In general, subsistence crops were damaged more severely than cash crops. Maize, millet, and cassava were damaged severely (>50% loss) more frequently than cotton (Fig. 3). Grains, fruits, and non-root vegetables had similar rates of severe damage, followed by root vegetables. Cash crops were severely damaged at the lowest rates (Fig. 3).A single report at the household level could include damage to more than one crop type. Damage to grain crops was reported most often. In total, 157 livestock were reported damaged during the study period (142 killed, 15 injured);

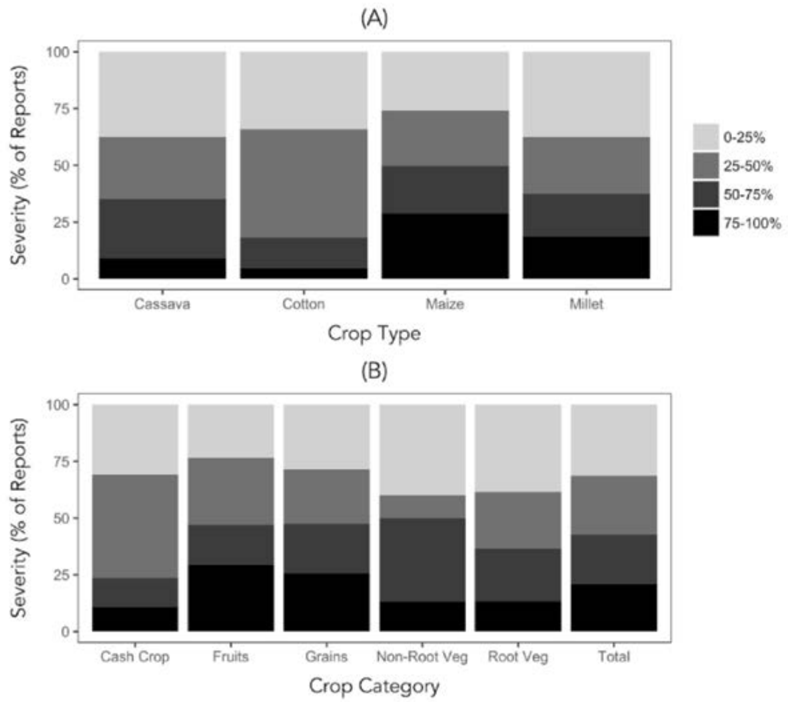

Figure 3: *Severity of damage reports for (A) the four most commonly damaged crops and (B) by general crop category. The legend indicates the percent loss. A lower proportion of reports of cash crop (such as cotton) damage were severe (>50% loss).*

Table 3: Total reports of elephants damaging crops, by crop type and general category as reported to and verified by village agricultural officers.

Crop Type	General Category	Reports	Crop Type	General Category	Reports
Maize	Grains	206	Banana	Fruit	4
Millet	Grains	81	Melons	Fruit	2
Rice	Grains	18	Mango	Fruit	1
Cassava	Root veg	88	Oranges	Fruit	1
Sweet potato	Root veg	16	Cotton	Cash crop	44
Mixed veg.	Non-root veg	18	Sugar cane	Cash crop	5
Beans	Non-root veg	15	Sunflower	Cash crop	3
Onion	Non-root veg	2	Sisal	Cash crop	2
Peas	Non-root veg	2	Tobacco	Cash crop	2
Tomato	Fruit	12	Sesame	Cash crop	1

considering fatalities only, this equates to a 15% loss in livestock holdings per report on average. Lion depredation was reported most frequently followed by hyena and elephant. As measured by the total livestock killed per report, hyena predation events were most severe on average (Table 4). Elephants were reported to exclusively kill cattle; while hyena and lion damaged a more diverse array of livestock, overall hyenas primarily preyed upon shoats (74%) and lions upon cattle (73%) (Fig 4).There was a strong, negative association between the percentage of the herd killed and herd size, which was statistically significant (r_s = -0.6997, p < 0.001).

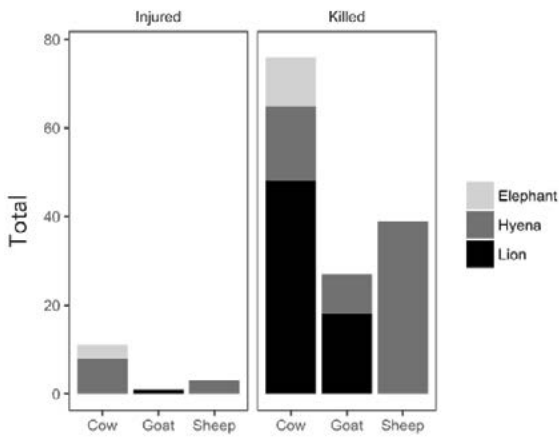

***Figure 4**: The number of livestock killed by livestock type and wildlife species. Elephant and lion tended to kill cattle almost exclusively, while hyenas were reported to primarily kill sheep and goats.*

Table 4. Report characteristics of livestock damage instances reported to and verified by village agricultural officers. Average severity only considers livestock fatalities.

Category	Species	Totals
Reports	Elephant	6
	Hyena	13
	Lion	18
Total Livestock Killed	Elephant	11
	Hyena	65
	Lion	66
Average Severity	Elephant	1.8
	Hyena	5.0
	Lion	3.7

DISCUSSION

Household surveys can provide baseline data about human-wildlife conflict, help to establish management priorities, and aid in identifying appropriate mitigation strategies. However, damage estimates from self-reported losses may be biased towards larger species, or inflated because respondents believe there could be some indirect benefit (e.g. via outreach activities) in doing so (Holmern & Roskaft, 2013). Opportunistic sampling through a reporting network can be problematic in that people may be biased in the types of losses (species, extent of damage) that they report. Here, we utilized both of these approaches in an attempt to present a more complete picture of the extent and severity of conflict between people and large mammals in the western Serengeti. Estimates of households experiencing conflict obtained in our systematic household survey may be higher than if obtained via other sampling procedures because of a sampling bias towards rural households, but this approach provides better spatial coverage and an understanding of the geographic extent of damage.

Results indicate that crop damage by elephant is the most pervasive form of HWC in the western Serengeti, but that the depredation of livestock is more common than expected based on previous assessments of government records (Snyder, 2016). Responses indicate that household security and ability to absorb losses is low, which makes the widespread nature of damage to household resources by wildlife particularly impactful.

In the western Serengeti, people reported that their greatest concern surrounding crop production is the threat posed by wildlife. In a system where many other factors contribute to successful harvests, this may seem unexpected, but given the reported extent and severity of crop losses to wildlife, is warranted. Crop damage by elephants is widely distributed across the landscape; coordination between government, NGO, and community partners is required in order to develop comprehensive strategies and early-warning systems.

Currently, people primarily employ reactive approaches at the risk of physical harm in order to deter elephants – guarding fields, and chasing and shouting at elephants when they appear. Field-level deterrents will be an important component of any mitigation strategy, but greater effort should be directed towards identifying appropriate deterrents based on local environmental characteristics. Strategies that do not require people to put themselves at physical risk by interacting with elephants directly and by foot should be prioritized.

Others have suggested that planting unpalatable cash crops may be one strategy to reduce the occurrence and severity of elephant damage to crops (Parker & Osborn, 2006; Sitati & Walpole, 2006). This study area, people reported damage to cash crops such as cotton, tobacco, sunflower, and sesame, which are presumed to be less palatable than grains, fruits, and vegetables. While these crops were still damaged by elephants, it was found that the occurrence of severe damage was less frequent. The total number of cash crops reported damaged was far fewer than those of consumptive crops, but whether this is meaningful is not clear because information on the availability of different crop types is not available.

Livestock loss to carnivores was common among herding households, but concerns over productivity, grazing land availability, weather, and disease all out-ranked wildlife as threats to livestock. This does not indicate that livestock damage by wildlife should be ignored – the links between carnivore predation on livestock and retaliatory killings are well documented (Inskip & Zimmerman, 2009). Instead, this knowledge can be applied when designing programs that aim to reduce the impact of livestock depredation at the household level through both direct and indirect measures.

For example, developing comprehensive livestock husbandry programs should incorporate best practices for preventing losses to carnivores as well as additional programs targeting reductions in other sources of livestock loss that will improve household security and resiliency to damage events. Options include veterinary clinics to treat and prevent disease, rangelands management programs to improve the productivity of grazing lands, and emphasizing increasing household assets by producing healthier, more valuable animals (rather than the dominating philosophy to do so by acquiring more livestock). In the western Serengeti, programs like these would especially benefit households with smaller livestock herds. The proportion of livestock killed was negatively associated with herd size –households with few livestock, those that are expected to be least able to absorb a loss, are most vulnerable to the effects of livestock depredation.

The retaliatory killing of lions in response to livestock loss is a conservation concern in the western Serengeti. Since 2014, at least fourteen lions have been poisoned or shot in adjacent villages (Steffen Cunliffe, Director at Singita Grumeti Fund, personal communication). As demonstrated by our results and others elsewhere (eg. Holmern *et al*., 2007; Kissui, 2008,), lions tend to prey on cattle, the most valuable type of livestock. This is one reason why responses to lion depredation are thought to be particularly volatile (Kissui, 2008). Locally, this means that additional efforts should be developed to target areas where lion depredation occurs for additional, direct intervention. As our results indicate that livestock losses to lions are relatively rare, this should be feasible. In the future, the results of our survey will be used to develop spatial predictions of human-lion conflict in order to inform spatially targeted interventions.

In general, our results indicate that crop damage by elephants is the most widespread form of conflict in the western Serengeti and should be a top management priority in order to reduce the burden of wildlife on people, and to increase local support for conservation efforts. As resources are limited and damage is widely distributed, effective strategies will require coordination between community members, government agencies, and NGOs.

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INTERACTIONS BETWEEN MAASAI CULTURES AND WILDLIFE: THE KILLING OF BIRDS DURING "SIPOLIYOKISHU", A PRE-MORAN STAGE

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ABSTRACT

Wildlife is used in many cultural practices and is especially popular in Maasai tribe. Some of these practices have negative impacts to wildlife population as they involve killing. Rituals killing of wild animals such as lion by Maasai (Alamayio) have been documented in East Africa. However the killing of birds during 'Sipoliyokishu', a pre-Moran stage (i.e. from Ilayook to Moran), although common have not been studied and its conservation implication is unknown. In this study attempts have been made to assess and document the ritual killing of birds in the Maasai community in northern Tanzania. Questionnaires were used to collect information with intention to identify the affected bird species. The questionnaire method was followed by field survey of birds within the sampling villages to ascertain the status of the species used during the transitional period. A sample of 24 and 26 'bomas' or households from a total 94 and 102 were picked from Oloirobi (Ngorongoro district) and Esilaei (Monduli district) villages respectively. One person was interviewed from each 'boma'. A total of 97 bird species belonging to 43 families were recorded using both Timed Species Count and opportunistic observations. About 71% of total species are involved during "Sipoliyokishu" rituals, they include migrants and endemics. Although this event is part and parcel of Maasai traditions and it occurs at least every 7 years, numbers of boys participating in the event is increasing (each boy kills a minimum of four birds) and this could affect the mostly preferred species given their ongoing habitat changes in the 'Maasai land'. The study recommends conservation awareness and education to the Maasai community especially the elders on the possible long term effects of 'Sipoliyokishu' rituals and encourage them to use other alternatives instead of killing birds.

Key words: *Birds, conservation, Maasai traditions, Moran, Sipoliyokishu*.

INTRODUCTION

Culture refers to the totality of beliefs that humans use to shape their daily lives, relationships, behaviours, activities, and ultimately their laws and policies (Orbach *et al*, 2010). It is via culture, a certain society determine the use of the resources surrounding them. Maasai culture, like any other traditions, is a dynamic phenomenon that evolves to adapt to new circumstances and includes a set of values and practices that is associated with a particular way of life. Maasai people occupy arid and semi-arid rangelands in southern Kenya and northern Tanzania; collectively known as 'Maasailand'. Maasai people maintain a semi-nomadic pastoral lifestyle and other traditional activities (Ikanda & Packer, 2008; Hazzah *et al.,* 2009).

The Maasai are well known for practicing age set organization, whereby each member of the society is assigned responsibilities and duties according to age and sex. This kind of labour division provides a unique and popular identity of the Maasai tribe. Typical Maasai lifestyle in each age-set still depend largely on surrounding environment. Young Maasai are trained by elders from childhood to adulthood to survive in the surrounding environment (Maundu *et al.,* 2001) and learn traditions and rituals. Ritual means actions that are usually prescribed by a religion, or by the traditions of a community or by political laws because of the perceived efficacy of those actions. Hendry (1999) defines ritual as behavior prescribed by society in which individuals have little choice about their actions. In Maasai traditions there are many rituals. One of those rituals is killing of birds by circumcised boys during a pre-*Moran* stage known as *Sipoliyokishu* which is conducted following a prescribed form and order (Saitoti, 1986). *Moran* is a Maasai adult man or soldier.

Sipoliyokishu (in Ma) is a transitional period from '*Illayook*' to '*Moran*' i.e. the period after a circumcision that a boy passes before to become a *Moran*. Circumcision *(emorata)* is defined by Maasai as cutting of a foreskin of the penis, the most sensitive part of the body, using a sharp knife (Saitoti, 1986). During this action a boy is not allowed to budge, move a muscle or even blink the eyes. The slightest movement on any of his body part will mean he is a coward, incompetent and unworthy to be a Maasai man. Maasai call this action "*aipirio*" or "*ekweta*" (to run away), and the one who behaves in this way is referred as "*orkaisiodi*".

Sipoliyokishu is a bird killing stage. Birds are killed, skinned and stuffed with dry grasses, and made in head ring/crown which they wear throughout the stage before they graduate to become *Morans*. The circumcised boys kill birds by using wooded clubs, throwing arrows that are covered at the tips with honey wax and stones. Also, others go to collect them from their nests.

The type or species of birds killed by a boy is determined by the responses and acts that one makes during *emorata*. *Orkaisiodi* are assigned to kill mostly 'less valued birds' and strong boys kill 'beautiful birds or most colourful'. Circumcision in Maasai community is conducted every 4 to 7 years and banned in between in order for a new age set or a peer group (14-18 years old). All circumcised boys in that interval are grouped together in one peer group called "*alaji*". During this period the circumcised boys are groomed to become *Morans*. The killing and skinning birds is the main activity during *Sipoliyokishu*, and it lasts for two to four months. Thus this study was conducted to assess the extent and identify bird species involved and discuss its conservation implications.

MATERIALS AND METHODS

Study area

The study was conducted in classic Maasai villages at Monduli and Ngorongoro (within the Ngorongoro Conservation Area) districts, Northern Tanzania.

Monduli

Monduli district has an area of 6,419 sq. km. of which 6,290.62 km^2 is land area and about 62% of this land is a grazing area. 1,055.48 km^2 is arable land, 374.97 km^2 is under forest and water covers only 128.38 km^2. According to National Population Census of 2012 the district has 158,929 people with the growth rate is 3.9. The topography is characterized by a number of isolated mountains (Monduli, Lepurko and Loosimingori) and flat rolling plains. The District has mixed vegetation – forest, bush lands, wooded grassland and grasslands that harbor different kinds of wildlife. The Maasai constitute 60% of the entire population and more than 90% of the population in Monduli District is engaged in keeping livestock and agriculture.

Ngorongoro

Ngorongoro district lies in the north of Tanzania 90 km west of Arusha, adjoining the southeastern edge of Serengeti National Park between 2^0 30' to 3^0 30'S and 34^0 50' to 35^0 55'E. Ngorongoro Conservation Area Authority (NCAA) is found in Ngorongoro District in Arusha region. The NCAA was established in 1959 as multiple land use area designed to promote conservation of wildlife, other natural resources, interest of indigenous resident pastoralists and tourism (MNRT, 2006). The NCAA covers about 8,292 km^2. According to census of 2012, it has population of 174,278. The residents are mainly pastoralists with estimated to have over 300,000 cattle in NCAA and human population keeps growing (NGONET, 2008). The climate ranges from savannah, equatorial to temperate due to the presence of mountains. The area is rich in wildlife and birdlife is diverse (Kennedy, 2014). The area hosts endangered animals such as rhinos.

Study area and selection criteria

This study involved two villages, Oloirobi from Ngorongoro and Esilalei from Monduli. The two villages represents a typical Maasai culture with little influence from other tribes. The villages are in close proximity or within wildlife areas.

Study sites.

Esilaei is the village found in Esilalei ward Monduli district council. It is bordered by Manyara ranch that acts as dispersal wildlife areas as well as interlinkage between Lake Manyara and Tarangire national parks. Thus, the village is situated in the areas that are rich in wildlife (Kalavar, 2014). It is a typically Maasai village and most of villagers depends on livestock's while few are peasants.

Oloirobi is the first village found near the rim of the Ngorongoro crater. It is located in 3°12' 0" S, 35° 27' 0" E and found nearly 1 km from NCAA Headquarters. It is also a typical Maasai village and their main activities are livestock keeping while few of the villagers are employed by the NCAA. Its elevation is approximately 2,380 m above the sea level.

METHODS

Questionnaires

Questionnaires were used to collect information from the respondents. The aspects covered included; personal information, reasons for killing birds, factors for selection of birds to be killed and skinned by a circumcised boy, alternatives in the absence of a target species and their opinion on this activity in relation to conservation of birds. Systematic random technique was used, in which the starting *boma* (household) was selected randomly and the next was taken after every two *bomas*. A total of 50 people from two villages were interviewed. Oloirobi had a total of 94 *bomas* and 24 *bomas* were sampled and Esilalei had 100 *bomas* in which 26 *bomas* were visited. One respondent was picked randomly (the first encounter) from each *boma* but this excluded women and children. This is because women and children are not involved in killing and skinning birds.

Timed Species Count

The Timed Species Count (TSC) method was conducted in both study sites respectively. Bird species were recorded using TSC method following Pomeroy (1992), and Bennun and Waiyaki (1993). During TSC method, six field visits were made and bird species recorded in the intervals of ten minutes with each count lasting 60 minutes. Species were recorded after positive identification either by sight or sound, each receiving a score of 6 to 1 depending on the first time it was recorded.

Direct and opportunist observation

Also some of information were be obtained onsite via direct and opportunist observation during the data collection period.

Data analysis

The data from ritual killing of birds at *Sipoliyokishu* were analyzed by using the Statistical Package for the Social Sciences (SPSS) Version 20. The information concerning species richness, commonness and relative abundance were analyzed by Timed Species Count method (TSC). In which the interval of ten minutes were used and all birds species encountered at this time are recorded without repeating it for an hour. The mean score and rank for each species were calculated. Also Sorensen similarity index (*Ss*) for the two study sites was calculated.

RESULTS AND DISCUSSION

Avian composition in Oloirobi and Esilalei

A total of 97 bird species from 43 families were recorded in both sites by using TSC and opportunistic methods. In Esilalei, 51 bird species were recorded through TSC and 21 opportunistically. Likewise at Oloirobi, 49 and 28 bird species recorded via TSC and opportunistic methods respectively.

From TSC data, mean scores were computed and then ranked. High mean scores represents common species in the study area. Common species at both Esilalei and Oloirobi are shown in Table 1 and 2.

In both sites, the species with lower mean scores are considered to be rare species, and unfortunately they are the most target species during *Sipoliyokishu*. In Esilalei, the less common species included; red-fronted barbet, white browed coucal, white throated bee-eater, African orange-billed parrot and European roller. Similarly in Oloirobi, white-browed robin-chat, Schalow's turaco, tropical boubou and red-billed buffalo weaver were less common. The two study sites were found to represent different a bird community with as low as 35% similarity index. Oloirobi village had more species compared to Esilalei. The difference is due to different habitats and altitude (Kennedy, 2014). Open habitats at NCA favoured rufous-naped lark, capped wheatear, Jackson's widowbird, red-collared widowbird and Schalow's wheatear, species not found at Esilalei. High altitude marshes favoured fan-tailed widowbird (Stevenson & Fanshawe, 2006).Some of the species recorded during this study were Palearctic migrants namely black kite, European roller, black stork, Abdim's stork, common sandpiper, yellow wagtail, barn swallow, sand martin, and intra-Africa migrants such as white-throated bee-eater and grey heron (Githiru *et al*., 2009). Threatened and endemic bird species were common and are also killed during *Sipoliyokishu*. Ashy starling and fischer's lovebird are endemic to Tanzania while Schalow's turaco is endemic to East Africa. Additionally, Schalow's wheatear is endemic to the rift valley of Kenya and Tanzania (Stevenson and Fanshawe, 2006).

Table 1: Ten most common bird species recorded in Esilalei in March, 2016

Common name	Species name	Mean score	Species Rank
Rufous tailed weaver	*Histurgops ruficaudus*	6.00	1
Superb starling	*Lamprotonis superbus*	5.67	2
Fischer's lovebird	*Agapornis fischeri*	5.33	3
Ring necked dove	*Streptopelia capicola*	5.00	4
Red billed buffalo weaver	*Bubalornis niger*	2.33	5
Red and yellow barbet	*Trachyphonus erythrocephalus*	2.33	5
Von der Decken's hornbill	*Tockus deckeni*	2.00	7
Rosy patched bush shrike	*Rhodoophoneus cruentus*	2.00	7
Laughing dove	*Streptopelia senegalensis*	1.83	9
Namaqua dove	*Oena capensis*	1.83	9

Table 2: Ten common bird species recorded in Oloirobi March 2016

Common name	Species name	Mean score	Species rank
Baglafetch weaver	*Ploceus baglafecht*	5.83	1
Streak seed eater	*Serinus striolatus*	4.50	2
Fiscal shrike	*Lanius collaris*	4.167	3
Black crow	*Corvus capensis*	4.167	3
Jackson widowbird	*Euplectes jacksoni*	4.000	5
Common stonechat	*Saxicola torquata*	3.83	6
Abdim's stork	*Ciconia abdimii*	3.50	7
Rufous- naped lark	*Mirafra africana*	3.167	8
Red- collared widowbird	*Euplectes ardens*	2.50	9
Grassland pipit	*Anthus cinnamomeus*	2.00	10

Ritual killings of birds by Maasai during Sipoliyokishu

Fifty respondents ranging from 18 to above 70 years (Table 3) were reached during this study, 24(48%) interviewed from Oloirobi and 26(52%) were from Esilalei.

Maasai kill and skin birds for multiple overlapping reasons (Table 4). Decorative purposes (36%) and part of traditions (30%) were the most frequent answers given by the respondents followed by prestige and pleasure (14%). Birds with bright colour patterns are the most targeted during the killing, as they are considered beautiful. Over 86% of respondents believed that the choice for a particular bird species is influence by colour while 14% mentioned bird behavior. Colourful birds are assigned to non-flinched boys and the dull to flinched boys '*Orkaisiodi*' (Saitoti, 1986; Slites n.d). The aims of assigning dull coloured birds are an insult to a boy within the peer group and the Maasai community. Overall each boy kills between 4 birds (70% respondents) to 8 birds (30% respondents). Maasai believe that even numbers are perfects (*'esinyari'*). They believe that doing things in even numbers is being perfect leading to right decision making and is associated with blessings. Fortunately large birds are not involved in the killings although parts of the body of some species are used.

Table 3: Age group of interviewed respondents

Reason for killing birds	Frequency	Percent
Inyangulo (18-24)	8	16.0
Ilkorianga (25-40)	8	16.0
Ilking'onde (41-55)	18	36.0
Ilmakaa (56-69)	9	18.0
Ilseuri&Ilmeshuki (70+)	7	14.0
Total	**50**	**100.0**

Table 4: Different reasons given by respondents as why they kill and skin birds

Reason for killing birds	Frequency	Proportion (%)
Decorative purposes	18	36.0
It build cooperation among the group	4	8.0
A part of tradition	15	30.0
Pleasure and prestige	7	14.0
Superiority and strongness	3	6.0
Decorative and to bring cooperation among the group	2	4.0
Decorative purpose, build strong and cooperative group and to fasten healing of the wound	1	2.0
Total	**N= 50**	**100.0**

For example, ostrich's feathers and egg shells are sometimes collected and used by the boys. Egg shells of ostrich are used at an early stage of initiation of circumcision and the ostrich feathers are used as decorative materials by the circumcised boys. Maasai believe that using ostrich's egg shell brings good fertility and wealth (many cattle) in the family. Large birds are difficult to hunt, kill and skin. Other large birds such as bustard, cranes, flamingoes, secretary birds, hamerkop, storks, herons, crows and all birds of prey although common in the area are not involved in this stage.

Alternatives to killing birds

Furthermore, Maasai culture provides room for the use of alternatives in case the targeted species is not available. Although 46% of the respondents didn't not prefer or recommend use of alternatives, 54% mentioned that dried donkey dungs can be used instead of birds. The dried donkey dungs are used at the day of graduation from '*Sipoliyokishu*' to 'Moranhood', for those that were unable to kill any bird or lost their bird head rings/crowns. At the day of graduation four dried donkey dungs are used as alternative for birds and are arranged on the tradition chair and milk is poured onto. The meaning of doing so is like baptism in Christianity, thus a boy is cleansed and he is not allowed to kill birds again in his life and he is ready to start adulthood stage.

Conservation implications and future prospects

In this study data shows that many local species (over 70%) reported in the study villages are involved in *Sipoliyokishu.* The most treasured birds are turacos, lovebirds, starlings, barbets, tchagras, coucals, bee-eaters, rollers, weavers, shrikes, woodpeckers and oxpeckers. Others are mouse birds, hornbills, go-away birds, helmeted guinea fowls and francolins.

It is unfortunate that some species are killed while on nests and many are injured in the process. As population grows in the study area, currently at 3.5% which is above the national population growth rate, bird killings will also increase. This is because many boys will be circumcised. Potential impacts on birds especially the more valued of this tradition (Reson, 2012) is very high. Some of these species e.g. lovebirds are endemic to the region.

Traditions are part of life, and striking the balance between tradition practices and conserving wildlife has never been easy but a possible venture. Fortunately Maasai community is dynamic and Maasai are ready to accept changes albeit slowly. Table 5 below indicates a range of opinions of respondents on the possible ways to address the killing of birds.

While over 30% suggest that circumcision and *Sipoliyokishu* should continue without killing of birds, 44% of the respondents suggested that the Maasai community should be made aware of the effect of the killing of birds through environmental education. Most of the respondents from the age of 18 to 40, suggested education to be provided to the society and people to carry out circumcision without killings birds respectively. This is a positive recommendation and it might be due to the increased interactions with other cultures, and formal education among the young peers. Nonetheless, others, mostly elders, (24%) do not welcome any changes or alternative to killing birds.

Table 5: Opinions of the respondents on ritual killing of birds

Opinions of respondents	Frequency	Percent
To educate the society on the impacts of this activity	22	44.0
Activity should go on as to keep our traditions	12	24.0
People should carry out circumcision but without killing birds	15	30.0
Should go on since it prevent further killing of birds in Maasai life	1	2.0
Total	**50**	**100.0**

CONCLUSION

This study documents one of the less known interaction between Maasai culture and wildlife. Although *Sipoliyokishu* is not conducted more often, increase in participating individuals due to population increase in the Maasai community is likely to cause a significant impact on target bird species in a long run. The most valuable birds are the brightly coloured species which unfortunately include endemic and migrant species. Moreover, the willingness to use alternatives such as dried donkey dungs instead of killing birds by Maasai and their suggestions for community awareness are positive signs for conservation. Therefore, governmental institution such as Malihai Club of Tanzania and community organizations dealing with conservation could take this as an opportunity to provide environmental education awareness especially on the traditions which do not align with wildlife conservation within 'Maasai land'.

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MAPPING AND UNDERSTANDING THE RISK OF ILLEGAL ACTIVITY IN THE WESTERN SERENGETI

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ABSTRACT

Illegal activity within protected areas is often in conflict with management objectives, and can undermine conservation efforts. In the western corridor of Serengeti National Park, Tanzania, the Grumeti and Ikorongo Game Reserves and Ikona Wildlife Management Area provide an important buffer between permanent settlements and the national park, while simultaneously maintaining critical wildlife habitat. Understanding where and why illegal activity is likely to occur in this system can assist managers in implementing more effective strategies to reduce illegal activity, but its cryptic nature makes diagnosing temporal and spatial dynamics in illegal activities difficult. A ranger patrol based records of illegal activity incidents occurring between 2013 and 2016 within the study area was examined. Illegal activity specific models for active hunting was constructed, bushmeat possession, livestock grazing, snaring, and tree-felling using MaxEnt, a machine learning technique that uses presence-only data, from which a spatial predictions of the likelihood of different activities was developed. From these outputs, we identified the environmental variables predictive of risk for each activity and examined the areas where illegal activities were most likely to occur. Results indicated that in general, risk was highest along the edges of reserves and extended into permanent settlements, and was positively associated with distance from roads and scout camps. Activities associated with wildlife offtake (bushmeat possession, hunting, snaring) were the most widely distributed in the study area.

The prediction and visualization of illegal activity within protected areas has the potential to provide managers with useful insights that can be used to better allocate resources dedicated towards the prevention of illegal activity. In the western Serengeti, this information could be used to design scout patrols emphasizing coverage of areas further removed from permanent camps, and identifying villages for the establishment or strengthening of community outreach programs related to the consumption and distribution of bushmeat.

Key-words: *Illegal activity, protected area, Serengeti, MaxEnt*

INTRODUCTION

Tanzania contains one of the world's most impressive systems of reserves designated for conservation – more than 30% of the land surface of Tanzania is legally designated as protected areas (World Bank, 2017). These reserves are subject to the pressures of a rapidly growing human population. The population of Tanzania is expected to more than quadruple by 2100, which would make it the fifth most populous country on the planet (Caro & Davenport, 2016). Protected areas will become increasingly important for the maintenance of wildlife populations, but will also be more vulnerable to the impacts of people and the demand for natural resources.

Most notably, protected areas are threatened by agricultural expansion, infrastructure projects, and illegal activity, such as hunting, grazing, logging, and firewood collection (Brandon, 1998; Caro & Davenport, 2016).

The western corridor of the Serengeti is part of an extensive network of protected areas known as the Greater Serengeti Ecosystem. This region contains extensive wilderness, Pleistocene levels of wildlife abundance, unique migratory events, two World Heritage sites, two Biosphere Reserves, and is considered a key landscape for conservation (European Commission, 2016).

The western corridor specifically maintains critical habitat that protects the seasonal herbivore migration, and acts as an important buffer between the core habitat of Serengeti National Park and permanent settlements. This area is challenged by the highest density human population adjacent to the national park (NBS, 2012), and is speculated to pose the greatest threat to the integrity of the ecosystem (Thirgood *et al*, 2004; Kaltenborn *et al*, 2005; Knapp, 2012). Previous research on illegal activity in this area has emphasized illegal hunting, including estimating offtake of wildlife populations (Dublin *et al*, 1990; Campbell & Hofer, 1995; Mduma *et al*, 1998) and consumptive preferences (Ndibalema & Songorwa, 2007). Others have also examined the factors that motivate people to engage in poaching and found that in general, poaching is motivated by a need to supplement the household food supply and income (Kaltenborn *et al*, 2005; Knapp, 2012). Although livestock grazing and tree felling for charcoal production are known to occur, these activities have not been systematically investigated in the western Serengeti.

In the face of a rapidly expanding human population, such as in Tanzania, maintaining the integrity of protected areas will require the support and cooperation of local communities, and deterrence of illegal or unsustainable extraction of natural resources within protected areas. The resources for law enforcement are limited and, therefore, must be applied efficiently in order to maximize outcomes. Identifying priority areas for intervention in order to reduce illegal activity is highly desirable, but often difficult. Information on personal engagement in illegal activity obtained through typical means (e.g. interviews, surveys) is highly sensitive, may be unreliable due to a desire of respondents to avoid self-incrimination, and typically lacks fine-scale spatial information (Nuno *et al*, 2013). Examining law enforcement records can avoid many of these issues if the data is reliably geo-referenced, but standard means of analysis (e.g. SMART) focus on providing information on hot-spots of detections across sampled areasand identifying gaps in patrol effort, rather than making inference on landscape features associated with illegal activities that can facilitate predictions of risk in non-sampled areas.

Geo-referenced law enforcement records are an example of presence-only data. In ecology, a number of modeling techniques have been developed and applied to presence-only species occurrence records. This suite of species distribution models (SDMs) relate species' occurrences to environmental variables by making comparisons between presence localities and background points, and produce spatial predictions of species' distributions (Elith & Leathwick, 2009). MaxEnt is one of the most widely used presence-only techniques because it produces robust predictions and is one of the most user-friendly techniques with regards to both model construction and interpretation (Merow *et al*, 2013).

While most commonly applied to species occurrence data, MaxEnt can be used to assess any form of presence-only data, including records of illegal activity. Others have applied MaxEnt to the study of wildlife poisoning events (Mateo-Tomas *et al*, 2012) and to examine the distribution of poachers within a national park (Jenks *et al*, 2012). Here, we apply MaxEnt to analyze law enforcement data, produce risk maps of different forms illegal activity in the western Serengeti, and to further our understanding of how environmental factors contribute to risk locally.

METHODS

Study area

The study area is located in northern Tanzania, covering 1,947km^2 of the western corridor of the Greater Serengeti Ecosystem (Fig. 1). The area is comprised of the Grumeti and Ikorongo Game Reserves, the Ikona Wildlife Management Area, the Sasakwa Concession, and a number of village-managed limited use areas that are designated for certain activities, primarily livestock grazing. This core area of interest is bordered by Serengeti National Park to the south and east, and permanent settlements to the north and west. In many areas, permanent settlements are established immediately along reserve boundaries and human activities extend into the protected areas.

The reserve complex provides critical habitat for a number of threatened species, including cheetah, elephant, leopard, lion, and recently reintroduced wild dog. The area also hosts large numbers of herbivores, preserves an important corridor for the seasonal migration of wildebeest, zebra, and gazelle, and acts as a buffer between permanent settlements to the north and Serengeti National Park.

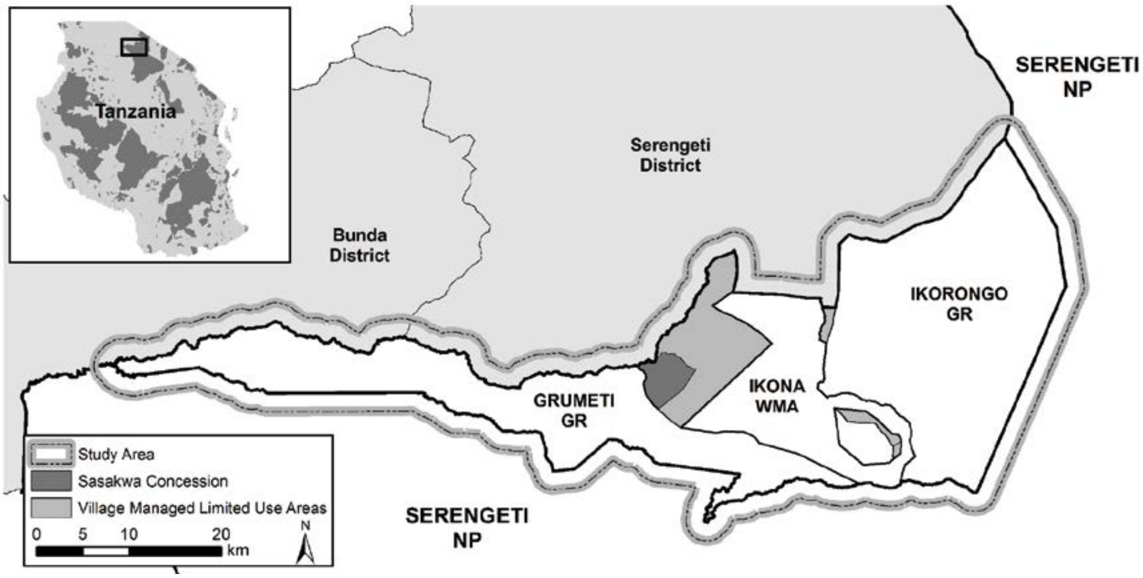

***Figure. 1.** Map of the western corridor of the Serengeti Ecosystem, with the study area outlined in gray. The area of interest primarily covers the Grumeti and Ikorongo Game Reserves, Ikona Wildlife Management Area, and adjacent village-managed limited use areas. The area also includes a two kilometer buffer extending into permanent settlements and Serengeti National Park.*

Data compilation

Law enforcement data collected between 2013 – 2016 were analysed, and were obtained from Singita Grumeti Fund (SGF), which manages the core landscape in coordination with the Tanzania Wildlife Authority, the WMA management team, and district and government officials. Serengeti National Park is managed by the Tanzanian National Parks Authority. Eleven SGF scout camps are distributed across the reserve complex; each unit undertakes patrols several times a week and uses a GPS to record their patrol path and the location and type of illegal activity events that they encounter.

Records for the five most common types of illegal activity events were taken – active hunting, bushmeat possession, livestock grazing, snaring, and tree felling for charcoal production. Only records containing GPS coordinates and enough information to reliably classify the incident into an activity category were included. Snare records were limited to cases where placed snares were removed, excluding incidents where people were found to be moving through the reserve carrying snares.

Model development

MaxEnt is a machine learning technique that utilizes presence and background data to model and predict environmental suitability across a geographic extent. The free MaxEnt software (version 3.3.3) was used and R packages 'dismo' (version 1.1-4) and ENMeval (version 0.2.2) to tune, construct, and evaluate all models (Muscarella *et al*, 2014; Phillips *et al*, 2015; Hijmans *et al*, 2017; Muscarella *et al*, 2017). A separate models was constructed for each form of illegal activity. Multiple environmental layers were used to assess landscape characteristics related to illegal activities, including elevation, slope, distances to rivers, roads, scout camps, and villages, and the type of protected area (Table 1). In combination, these factors are expected to influence accessibility, the threat of detection by scouts, and the local suitability for different activities. Sampling bias in our detection data by sampling background locations according to scout patrol effort was used, which was calculated as the normalized line density of patrol tracks. Patrol tracks were compiled and analyzed using ArcMap 10.3.

Table 1. Environmental variables considered for modeling bushmeat possession, livestock grazing, active hunting, snaring, and tree felling within the study area.

Variable	Description	Rationale	Source
Elevation	Elevation, meters above sea level	Low elevations experience seasonal flooding and can be difficult to access, posing a barrier to engaging in and detecting illegal activity.	Strm-30m
Slope	Slope of the terrain, in degrees	Areas of high slope are difficult to access.	Derived from the DEM
River	Distance to nearest river	Riparian areas are more densely vegetated, providing cover, access routes, and desirable habitat for wildlife.	SingitaGrumeti Fund
Road	Distance to nearest road	Roads provide access routes into the reserve, but may also increase the threat of detection.	SingitaGrumeti Fund, digitized from satellite imagery
Village	Distance to permanent settlements	Areas closest to permanent settlements are the most accessible.	Tanzania National Bureau of Statistics
Scout Camp	Distance to nearest scout camp	The threat of detection is likely to rise with increasing proximity to scout camps.	SingitaGrumeti Fund
Management	Protected area designation	The designation of the protected area may influence people's willingness to engage in illegal activities within that area because of benefits received (or not), primary managing entity, etc.	SingitaGrumeti Fund

To appropriately tune the models, MaxEnt across a range of settings was executed, and used evaluation metrics to identify optimal model settings for regularization multipliers and feature-class combinations. Settings that minimized AICc scores was used; in cases where competing models were produced (DAICc< 2), area under the receiver operator curve (AUC) was used to decide between alternatives.

Model Validation

Five-fold cross-validation was used to first fit and evaluate each model. In this technique, the data set is partitioned into k equal groups and k-1 sets are used for training, with the remaining set used for validation. This process is then repeated k times so that all samples are used for training and validation, with each set being used for validation only once. As few observations of tree-felling were recorded, in this case jackknife model validation was used, where k is equal to the number of observation points, which has been demonstrated to be effective for sample sizes of 25 or less (Pearson et al, 2007).

To evaluate the models averaged AUC values across each set of cross-validated models was used. As others have criticized the reliance on AUC as a sole evaluation statistic for models constructed with presence-only data (Elith & Graham, 2009; Jiménez-Valverde, 2012), also measurements on the similarity of predictions resulting from the cross-validated models using Schoener's D statistics were taken, which ranges from 0 (no overlap between models) to 1 (models are identical) (Warren *et al,* 2008).

Risk assessment

The complete data sets were used to construct full models and to predict the risk of each type of illegal activity across the study area. Continuous predictions were used as the basis for discussing alternative approaches for prioritizing areas for management and intervention. Four alternatives for selecting priority areas were examined: 1) The combined predicted risk of all activities and management areas (Generalized x System-wide), 2) The combined predicted probability of all activities, but management units considered individually (Generalized x Unit-based), 3) Combined risk by activity according to ecological impact across all management areas (Targeted x System-wide), and 4) Combined risk by activity according to ecological impact by individual management unit (Targeted x Unit-based).

In each case areas covering the top 20% of risk scores were selected. In alternatives three and four, the target was on the risk of wildlife harvesting (active huntingand snaring).

Mapping the predicted presence-absence of each activity using the 10th percentile training presence to determine suitability thresholds was done; this approach was selected because minimizing false-negative predictions (mistakenly predicting areas where illegal activity is absent) is of primary concern in this conservation application (Pearson *et al*, 2007; Norris, 2014). The resulting maps were used to examine and compare the predicted spatial extent of each type of illegal activity.

RESULTS

The final dataset contained 642 events, comprised of active hunting (N=91), bushmeat transportation / possession (N=71), tree-felling for charcoal production (N=20), passive hunting (snaring) (N=156), and livestock grazing (N=304).

Evaluation metrics indicate that the resulting models have good predictive performance and are robust. Final model AUC values were high for all activities (i.e. > 0.7, Table 2). AUC scores of the five-fold cross-validated models were consistent and all performed better than random predictions (> 0.5 Table 2). AUC scores for the jackknife model validation indicate a high mean AUC, but that these scores are widely dispersed (Table 2). Closer examination of these scores indicates that 16 of the 20 models performed very well (AUC test scores > 0.7), with the remaining four producing low AUC scores (0.05, 0.11, 0.39, 0.4). The Schoener's D scores were very high for all models (> 0.9, Table 2), indicating that overall, the predictions are robust. The risk of all forms of illegal activity increased with increasing proximity to settlements and decreasing proximity to roads and scout camps. The influence of management status and elevation were more variable across activities, while slope contributed meaningful influence (contribution > 1%) only in the case of snaring events (Fig 2). The importance of each environmental variable, as measured by percent contribution and variable jackknife results, was variable across activities (Fig 2).

All activities extend into protected areas, but there are noticeable differences regarding their extent (Fig 3). Illegal livestock grazing is the most restricted, while hunting is the most widespread. In areas where the GRs and WMA act as a buffer between permanent settlements and the NP, livestock grazing is excluded from the NP and the extent of tree-felling is limited. Notably, all hunting-related activities extend into the NP. As all approaches to selecting areas of high management priority rely on identifying the top 20% of risk scores, each alternative selects the same total area (389 acres), but with differing spatial distributions (Fig. 4).

Table 2. Settings and results for cross-validated and full models.

Activity	*n*	FC	RM	AUC_{FULL}	Mean AUC_{TEST}	Range AUC_{TEST}	*D*	T
Active Hunting	91	L	4	0.72	0.69	0.64 – 0.72	0.96	0.32
Bushmeat Possession	71	LQHP	4	0.76	0.71	0.64 – 0.76	0.96	0.28
Grazing	304	LQ	0.5	0.84	0.83	0.81 – 0.86	0.92	0.19
Snaring	156	LQH	3	0.78	0.74	0.66 – 0.78	0.94	0.31
Tree-felling	20	LQ	3	0.82	0.75	0.05 – 0.99	0.94	0.39

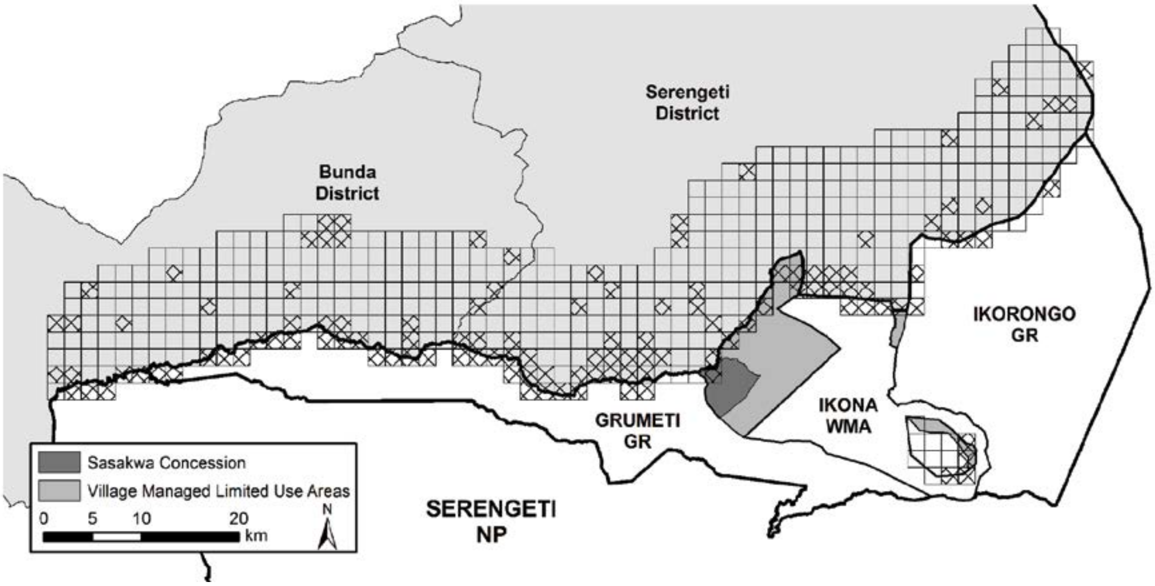

Figure. 2. *Significance of each environmental variable by type of illegal activity. Black bars indicate the percent contribution of each variable to the model, while the remaining two bars show the variable jackknife results. The dark gray bar demonstrates the training gain without the variable included, while the light gray bar shows training gain when considering only that variable.*

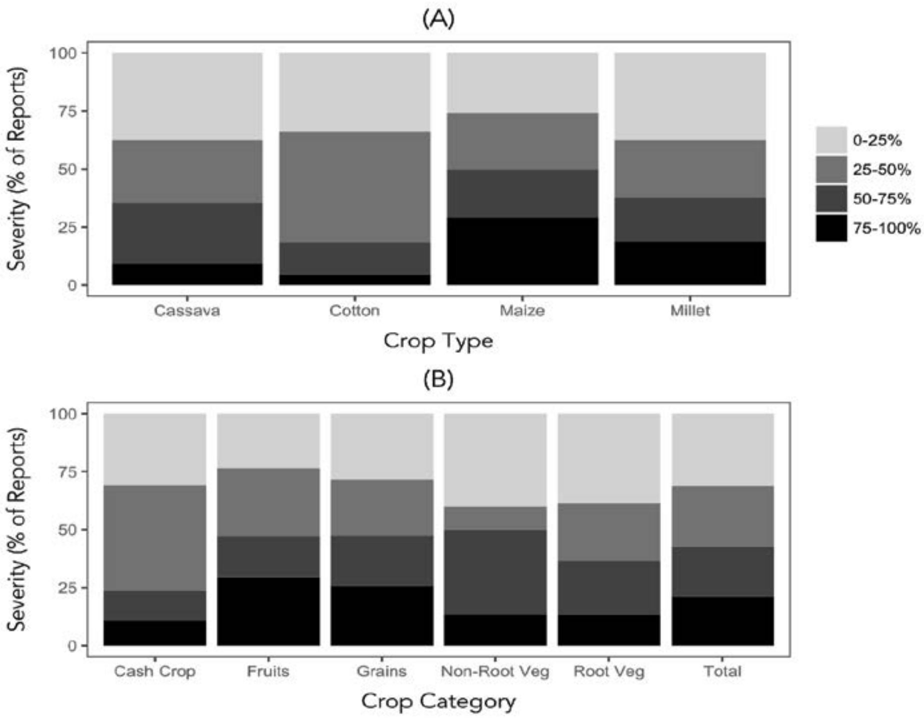

Figure. 3. *Spatial predictions of the distribution of each type of illegal activity across the study area. Continuous predictions (left) were used to identify the area of highest risk. A threshold was applied to distinguish between areas of presence and absence (right).*

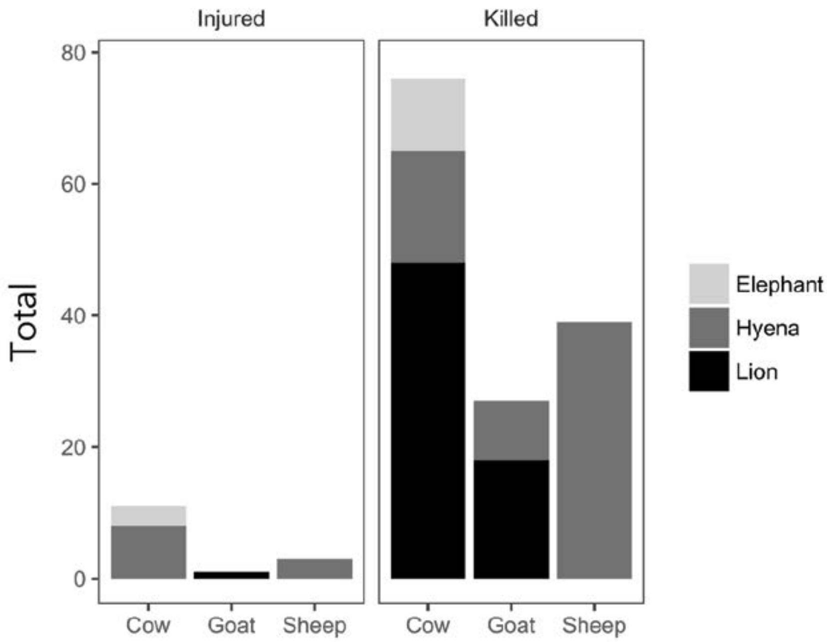

Figure 4. *Alternative scenarios for prioritizing management areas, with high risk areas identified in black.*

Each approach identifies 20% of the study area where illegal activity is most likely to occur. The generalized row selects priority areas based on combined predictions of risk across all forms of illegal activity. The targeted row selects priority areas based on high risk areas for active hunting and snaring only. The system-wide column identifies the top 20% of scores across allmanagement units. The unit-based column identifies the top 20% of scores in each unit.

DISCUSSION

The results identify the areas of the western corridor of the Serengeti Ecosystem at greatest risk of different forms of illegal activity, as well as the environmental factors that contribute to risk. The presence of game reserves and wildlife management areas insulates Serengeti NP from human impacts associated with livestock grazing and tree-felling. The risk of these activities was highly related to distance from permanent settlements - people are most likely to engage in these activities within a few kilometers of villages. The ecological consequences of these activities still pose a risk to the integrity of the GRs and WMA if unchecked, but the occurrence of grazing and tree-felling is limited in comparison to hunting-related activities.

Activities related to hunting include setting wire snares, actively hunting using dogs, pangas, knives, bows, and sometimes firearms, and being in possession of bushmeat. These activities were the most widely distributed throughout the study area, and present the most significant threat to local conservation efforts. As such, we highlight the specific nature of these activities, assuming they will be of the greatest interest for law enforcement efforts.

Bushmeat possession was typically detected when being transported within the reserve and in village areas. The predicted presence of bushmeatposession was prevalent throughout the study area, but risk was highest in village areas. It is logical that this would be the case –while bushmeat is transported within and out of protected areas, it ultimately ends up in markets and homes for distribution and consumption. The models suggest that bushmeat can be found along the entire reserve boundary, but risk is elevated in the east. Given that bushmeat detection tended to occur when transporting or in proximity to the consuming market, enforcement applications of predictive outputs for this activity are quite different from snaring and active hunting detection. The latter identifies where the illegal harvest is taking place, while the former provides inference on destination markets and transit routes.

Snaring is an indiscriminate form of poaching that makes no distinction between target

and non-target species – wildebeest, gazelle, elephant, and lions alike are all susceptible to this threat. In the western Serengeti, people tend to avoid placing snares right next to roads or scout camps, and while the risk of snaring is mediated somewhat by distance from settlements, the occurrence of snaring extends further from villages than either livestock grazing or tree-felling.Interestingly, proximity to rivers was not a particularly useful predictor of snaring propensity. Rather, our models predict that snaring is widely distributed across the study area, and extends into the NP in areas adjacent to the Grumeti GR and Ikona WMA. These areas of the NP are likely to be the most accessible, and therefore vulnerable, due to the geometry of Grumeti GR and the presence of Robanda Village within the WMA.

In terms of total predicted area of occurrence, active hunting is the most extensive illegal activity in the study area. Our models indicate that while people avoid roads, hunters are especially careful to limit the threat of detection by avoiding scout camps. The risk of active hunting was predicted to be highest within Serengeti NP. Active hunting techniques tend to be more conspicuous (e.g. more time spent within the reserve, muzzle blasts), and the threat of detection may be comparatively higher within the GRs and WMA due to an increased density of scouts and vehicles. Although people have to travel further to reach the NP, hunting there may be more attractive if discreet travel into the NP is possible and hunting activity is less likely to be detected there.

Managament Applications

The resulting risk maps can be used to identify areas for intervention in a flexible manner that reflects management priorities and facilitates the efficient distribution of limited resources. We present several approaches for leveraging these data for management intervention. The first was a generalized approach that combined predictions of illegal activities in order to identify areas where a number of illegal activities of equal priority co-occur.

This can direct management actions in areas of greatest risk overall. Given the nature of the illegal activities, those leading to the direct harvest of species may be of the greatest management interest. We present a targeted output for the case where select activities have been identified as the primary threats of interest, or when outreach and community development efforts are activity-specific.

In addition to development of predictive maps for all or select activities, we also present outputs focused on general spatial predictions across the study system and spatial predictions highlighting important areas within each management unit. The system-wide scale can be used in cases where government or oversight agencies pool effort and distribute resources across all management units, when individual agencies oversee or have influence in multiple management units, or to facilitate collaboration between multiple agencies in the same region. The unit-based scale is best used when individual management units are determining how best to allocate resources aimed at activities that are confined to their management unit. The outputs can support a range of decision-making, but managers should think carefully about which alternative aligns best with specific objectives.

In the western Serengeti, illegal activities associated with hunting wildlife are the most widespread and bear the greatest potential for undermining conservation efforts. A number of agencies manage the landscape and coordinate effort when possible.The illegal activities of primary concern extend across management boundaries, and occurrences in one unit impact adjacent units (e.g. consumption of bushmeat in village areas can drive hunting and snaring in game reserves). Given the serious ecological ramifications of direct illegal harvest, a targeted scope applied to identify harvest and transit locations summarized at a system-wide perspective may be the most critical for guiding enforcement.

While outputs from this analysis may be most applicable to policing efforts, inference gained through this analysis can also be used to target community outreach programs. We know that in this region the killing and consumption of bushmeat is strongly related to income shortfalls and the revenue potential obtained from poaching, and that those who have access to other revenue streams are less likely to engage in poaching (Loibooki, 2002; Knapp, 2012).Protected area managers and government officials can use the output derived from these models to create community outreach programs directed towards specific villages that are high risk areas for bushmeat possession and, likely, consumption (Fig 5). Programs should focus on the root causes of reliance on bushmeat, and could include economic development initiatives and promoting alternative sources of protein. As part of a multi-pronged approach, this can be paired with increased patrolling within protected areas in high-risk areas for snaring and hunting (Fig 4). Shaded areas represent the top 20% of risk scores system-wide, with the darkest areas at greatest risk. Seven priority villages for the development of bushmeat-specific community outreach programs are identified based on their proximity to the highest risk areas.

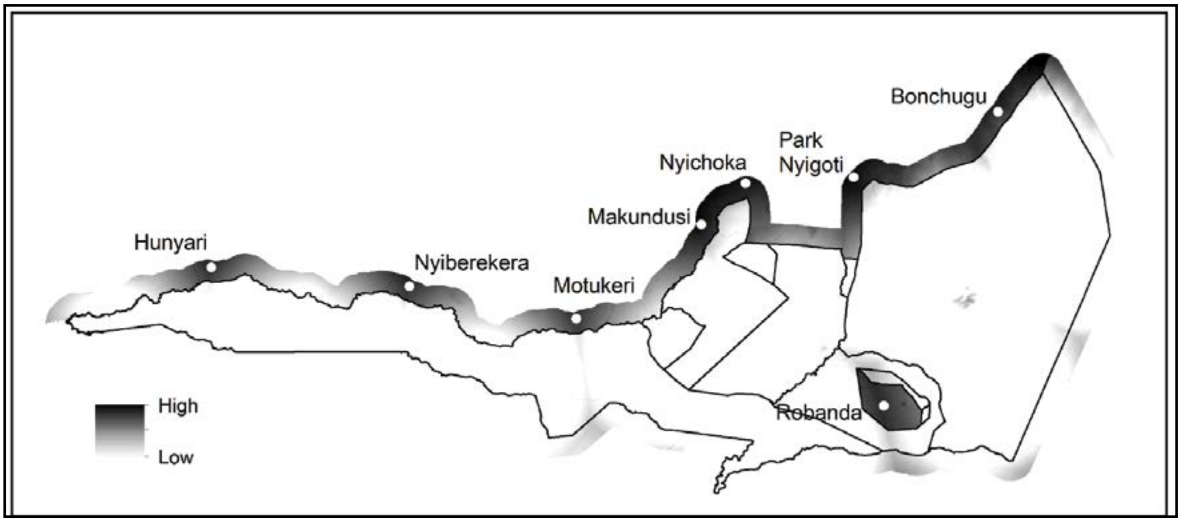

***Figure 5**. High risk areas for bushmeat transit and posession in the western Serengeti.*

Understanding the environmental factors that contribute to the occurrence of illegal activity can also guide decision-making. Our models indicate that in the western Serengeti, bushmeat possession, hunting, snaring, and tree-felling are all at a higher risk of occurring in areas further removed from scout camps. Local managers should incorporate this information into law enforcement procedures and fiscal planning. Options include more frequent patrols in areas further removed from camps, hiring additional scouts in order to cover more ground, utilizing temporary camps overnight to spend more time patrolling in remote areas, and planning for the construction of new permanent camps in identified gap areas.

Identifying where illegal activity is most likely to occur can contribute to the development of practical applications aimed at reducing the prevalence of these behaviors. The approach used here provides managers with spatially explicit tools and information to inform such approaches, without requiring the collection of difficult to obtain and sensitive information from people who actually engage in illegal activities themselves.

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THE STATUS AND CAPACITY OF VISITOR'S FACILITIES INSIDE AND ADJACENT SERENGETI NATIONAL PARK

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ABSTRACT
The rapid growth of tourism industry is an economic opportunity to Tanzania. However, there is an increasing concern for the few visitors the country is receiving, which has been thought to be associated with few accommodation facilities in the destination areas. The study was conducted in Serengeti National Park and adjacent areas, June 2015-February 2016 to assess the visitor facilities capacity, visitor's satisfaction and experiences and key ecological threats in relation to the accommodation facilities. The study used both qualitative and quantitative methods of data collection. Overall, qualitative data involved 62 participants who attended the focus group discussions (these included researchers, park wardens, park rangers and also selected few staff from accommodation facilities, in five organized Focus Groups Discussions) and 42 Key informants (lodge Managers, Park Wardens, long term researchers in Serengeti National Park, and Directors of Tour Operators). Qualitative data were analyzed using thematic analysis. The quantitative study involved administering 134 questionnaires to the targeted groups (Visitor's) and were analyzed using in the Statistical Package for the Social Sciences (IBM SPSS). Results revealed that generally, the park has all the necessary tourist facilities; most of them are located in the Central Zone. The occupancy rates for accommodation facilities varied among types, the most visited facilities had 51% (64%, n=32) occupancy rate in the peak season. The study also revealed that there is an increasing number of visitor accommodation facilities outside adjacent the park. Despite the fact that SENAPA appears to have adequate accommodation facilities, the only concern is an unequal distribution of the facilities and uneven distribution of visitor needs and attractions in some sites in the park. Majority of visitors interviewed were very satisfied 72% (n=134).Vehicle congestion at Seronera valley, increased wastes and its mismanagement, blockage of migratory routes were identified as key ecosystem threats related to visitor's facilities in the park. The study concluded that accommodation facilities are not the only means to increase revenue from tourism there are other tourist facilities need to be considered beforehand i.e roads, airstrips, visitor centres, toilets, picnic sites, shops, communication systems, and skilled staff. Therefore, results from this study will help the Management authorities in designing a mechanism that will help to develop tourism facilities while maintaining ecological health in order to achieve sustainable conservation and increase revenues.

***Key words**: Accommodation facilities, tourist, Serengeti National Park*

INTRODUCTION

Tourism is considered as a movement of people traveling outside their normal residential environment for the purposes of recreation, leisure, religious, family or business, etc., usually for a limited duration time for not less than 24 hours and not exceeding 365 days. Through consumption of local products such as accommodation, restaurants food, markets, attraction sites and additional expenditures outside the traditional tourist product. Tourists may also stimulate demands for agriculture, fisheries, food processing, light manufacturing products, such as the garment industry, as well as for handicrafts and the goods and services of the informal sector (Gisore & Ogutu, 2015).

Due to these tourists consumptive products, tourism is said to be an important driver of economic growth around the world, supporting an estimated 277 million jobs, generating US$7.6 trillion in indirect revenue, and supplying 9.8 per cent of global GDP in 2014 (Daly & Gereffi 2017). Moreover, the dynamism of the industry is not confined to any one region; while Europe and United state remains the most visited continents in the world, accounting for 51 per cent of all international tourist arrivals in 2014, Asia Pacific and Africa had the highest growth rates in visitors over the decade spanning 2005–2014 (Daly & Gereffi, 2017). The level of tourist satisfaction can heavily influence the prospect of repeat visits. Depending on the quality of wildlife viewing, accommodation, food, and personal interactions. Visitors with a satisfying experience may become repeat visitors or recommend the area to future clients.

Tourism in East Africa is based on wildlife viewing safaris (Okello *et al*., 2008) and is defined as among the world tourism destinations. In Tanzania, tourism is a leading foreign exchange earner (Daly & Gereffi, 2017) and is among the fastest growing economic sectors (Eagles & Wade, 2006; Okello & Yerian, 2009; Wade *et al*., 2001). This rapid growth of the industry represents a great economic opportunity for Tanzania among the developing countries (MNRT, 2009). However, needs to full fill the rapid growth of tourism industry should be treated with care, by considering how the country's vision towards sustainable resource conservation has been achieved.

Serengeti National Park (SENAPA) is the keystone attraction in Tanzania's important nature-based tourism industry (Eagles & Wade, 2006; Kaltenborn *et al*., 2011; Okello and Yerian, 2009). The park is famous for the large numbers of diverse wildlife and owing the highest biodiversity in the country (Sinclai & Arcese, 1995) SENAPA is considered a natural laboratory of outstanding local, regional and global importance and in this recognition, UNESCO designated the it as a World Heritage Site and a Biosphere Reserve (Mascia & Pailler, 2011; Marton-Lefèvre & Steiner, 2008). Serengeti is globally known for its annual Wildebest migration, and it contains the greatest remaining concentration of plains game in Africa (Rentsch & Packer, 2015) . Due to its unique diverse landscapes that support hundreds of wildlife, has attracted thousands of tourists from all over the world. Despite the fact that Tanzania is among the leading countries in terms of biodiversity richness and abundance of variety of tourist attractions with unique ecosystems there are increasing concern on the few visitors the country is receiving (Kaltenborn *et al*., 2011). This assertion is especially exacerbated by the fact that small protected areas like Maasai Mara Reserve in Kenya and countries like Seychelles are receiving many visitors per year, over and above Tanzania despite the fact that probably they have fewer attractions than Tanzania (Rentsch & Packer, 2015). Meaning that, the potential of the tourism industry in the country has not been fully utilized.

The assumption of the lower number of tourists the country is receiving has resulted into political and socio-economic pressures on the need to increase the number of visitors per year. To some extent the low number of visitors in the national parks like Serengeti has been also linked with insufficient visitor facilities such as number of beds to accommodate large number of tourists groups (Kaltenborn *et al*., 2011). On the other hand, there has been a concerns from conservationists that, the number of tourist is enough based on the national tourism industry's mission of developing quality tourism which is environmental friendly; thus, too many tourists and visitor facilities in a long run may cause adverse effects on the natural ecosystems (Kaltenborn *et al*., 2011). These two scenarios have continued to bring more questions and mixed feelings among the stakeholders and general public.

Little is known to whether the lower number of tourist arrivals in Tanzania is due to inadequate visitor facilities or something else. Furthermore, there is limited information on the capacity of visitor facilities in various protected areas especially in terms of facilicities available against number of visitors using those facilities; and whether the facilities are in full capacity throughout the year. The study thus aimed to investigate the status of visitor facilities, their capacities and perception of the visitor's on the quality of tourism based on their experience and satisfactions while visiting in Serengeti NP.

Objective

The study specifically had the following objectives:-

i. Assessing visitor facilities inside the park and adjacent areas, their capacity
ii. Assessing visitor's satisfaction and experience.
iii. Identify key ecological impacts related to visitor's facilities

MATERIAL AND METHODS

Study area

Serengeti National Park (14,763 km^2), located between 1°28'-3°17'S and 33°50'-35°20'E, forms part of the high interior plateau of Eastern Africa, was established as a Game Reserve in 1929, and as a National Park in 1940 (Sinclair & Arcese, 1995). In 1981, Serengeti became a World Heritage Site and an International Biosphere Reserve (Sinclair & Arcese, 1995). The Park is part of the larger Serengeti-Mara ecosystem and it covers several areas with different conservation status and administration (Figure 1). The ecosystem includes; Ngorongoro Conservation Area, Serengeti National Park, Maswa, Ikorongo and Grumeti Game Reserves, Loliondo Game Controlled Area. The Park occupies a vast upland area varying in elevation from 1,162 m.a.s.l. at Speke's Gulf of Lake Victoria to 1,860 m.a.s.l. in the Northeast. It has two defined seasons, dry season that starts from late May to October, and wet season from November to May (with a short dry season January-February). It receives the mean annual rainfall of 650mm in the south and 1,150mm in the north. The monthly average temperature is between 20˚ C – 25 ˚C, and day time ranges between 27˚C - 32˚C with a drop at night to 13˚C - 16˚C. Generally, the Park vegetation is of typical savanna in nature, dominated by savanna trees and shrubs, with an exception of the south-eastern corner that is dominated by open plain.

Study zones

During data collection three zones (Western, Northern and Central Zones) were considered, Northern Serengeti (Kogatende, Lamai and Wogakulya, Bilila, Mbuzi mawe, Lobo, Bologonja and Kleins), West Serengeti (Nyaruswiga, Kimarishi, Kirawira, Ikorongo & Grumeti Game Reserves, Ikoma and Ndabaka), Central Serengeti (Seronera, Banagi, Serengeti Wildlife Research Centre and Tana Spring) and adjacent protected areas.

Figure 1: *Study area Map of the Serengeti Ecosystem*

Research design

To accomplish the objectives of this study we used both qualitative and quantitative research design. The qualitative research design explored the opinions of participants and informants in relation status of visitor facilities, their perception on ecological impacts and threats related to visitor facilities in the park. Field observation was also used to assess quality of visitor's facilities and its impact on the ecology. The quantitative research design investigated visitor facilities inside the park and adjacent areas, their capacity and key ecological impacts related to existence of visitor's facilities.

Sampling strategies

Key informants were selected based on their roles and long term services in the tourism industry. The targeted groups were researchers, Park Wardens, Park ecologists, selected tour operators, and TANAPA Managers. For qualitative study such as Focus Group Discussions, participants were purposively selected based on experience with tourism based activities and ecological monitoring in the park. Main groups were researchers, park wardens, park rangers and also selected few staff from accommodation facilities.

Methods of data collection

The qualitative data were collected using checklists of questions, where by a total of 62 participants were interviewed through focus group discussion in order to gather information on their perceptions, views and recommendations on the status of visitor facilities, visitor trends and ecological impacts and threats related to visitor facilities in the park, Also 47 in-depth- interviews were conducted with Park managers, long term researchers, Park Wardens, Park ecologists, selected tour operators and accommodation facility manager and or owners. Direct field visit was also done by visiting direct the visitor facilities in order to collect information on type of the facility, capacity of the facility (i.e. number of beds, services), quality of the facility, availability of visitor requirement, assess ecological impacts and threats likely to occurred due to presence of visitor facilities and other tourists related impacts.

The quantitative data were collected using semi-structure interviews with the help of questionnaires which were physically handed to the respondents (visitors who were departing after completion of their visit in SENAPA, n=134). The questionnaires collected information on visitor's experience and satisfaction including, reasons for visiting SENAPA, perceptions on the environment in the Park, views on visitor numbers and their perception on the quality of tourism in general.

Other information was collected through secondary data from different institutions including SENAPA Tourism and Ecology Department, previous studies and other Tourists service providers.

Data analysis

The qualitative data were analyzed by content analysis focusing on the recurrent themes in the text. The analysis involved transcribing the interviews information, identifying key themes and coding of the themes. The themes that emerged from the data collected corresponded to the research questions and specific objective.

Quantitative data

Most of data were nominal therefore non-parametric statistical tests were performed. Pie charts and bar graphs were used to summarize information about bed capacity of the visited accommodation facilities and facility's occupancy rates.

RESULTS AND DISCUSSIONS

Status of visitor facilities inside the park and adjacent areas.

A total of 32 visitor's accommodation facilities were visited during the survey. Of these, ten (10) were lodges (five inside the park and five outside adjacent to the park); eleven (11) permanent luxury tented camps (Seven inside and four outside the park), two (2) mobile camps and nine (9) public campsites (located inside the park). In these facilities, a total of 657 rooms and 2,455 beds were counted both from inside and adjacent the park. About 86%, n=2,455 of tourists beds counted were found in the tourist facilities within the park while 14% found in the tourist facilities adjacent the park boundary, mainly on Western and Eastern Zones. Accommodation facilities such as mobile camps were not included because they are on seasonal and were not all visited during the survey. Of the total counted beds, 88% (n=2,455) of the visited accommodation facilities were permanent facilities (Lodges and Luxury Tented Camps). It was also noted that, 24% (n=32), of them had more than 20years of their establishment, indicating that majority of the facilities were at their initial operation stages and they are newly developed. It was noted that majority of the visited facilities had between 11-20 rooms with bedding capacity of between 21-30 (figure 2a and 2b), this category falls under Luxury permanent tented camps. The second group comprised of lodges that had more than 50 rooms with bed capacity above 80 per facility (figure 2). Although we did not manage to survey all the tourist facilities but based on the SENAPA GMP, 2014 it appeared that the park has 1,362 beds (794 from lodges and 568 in Permanent Tented Camps). TANAPA has indicated that, there has been an increased visitors number for Serengeti NP annually which implies that, a need to add more rooms and beds has to be considered as an urgent need (SENAPA GMP 2014-2024). Though there is a high need and good proposals that care should be taken to save the ecological integrity of the park. It was also observed that, the main reason for maintaining low number of rooms and bedding capacity at permanent tented camps was related to high quality services provided for a small group of tourists to meet their high satisfaction and excellent experience. Results from the visited facilities, indicated that most of the facilities become fully occupied during high season in tourist's peak (July - September).

Occupancy Rates of accommodation facilities

For many years, Serengeti being a model National Park among many other protected areas in Africa, has managed to maintain its nature as stipulated in the park Management Plan of 2006-2016. "That the Park will continue to provide an outstanding experience for both local and international visitors, increasing optimal economic benefits at national level, TANAPA, Private sector, local communities while maintaining a minimal impact on the park's resource value". Majority of accommodation facilities that were visited (64%, n = 32) had an occupancy rate of above 51% (Figure 3), followed by those that had between 41- 50% occupancy rate. Although there is a claim that, Seronera area is the highly congested zone especially during high tourist season the study noted that Northern, Western and Southern facilities were e also full occupied in the high season. However, unlike the facilities at the Central Zone, facilities in the Northern, Western and Southern Zones operated seasonally with more dependence on wildebeest migration. In low season, most of the facilities (56%, n=34), were

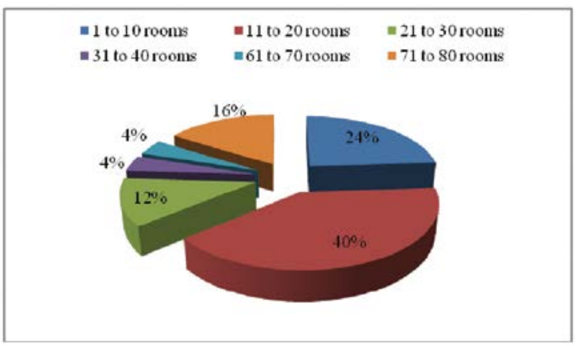

Figure 2 (a): *Room capacity*

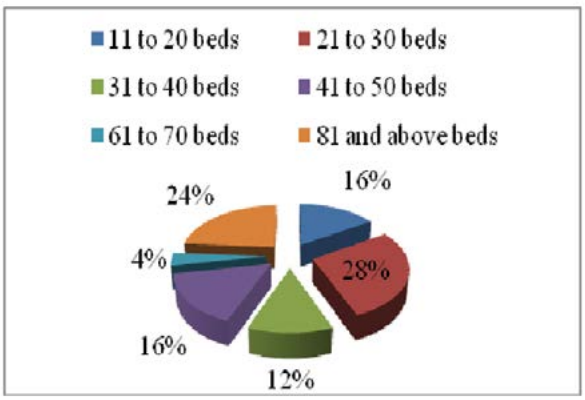

Figure 2(b)*: Bed capacity of the visited accommodation facilities both inside and outside the park* observed to have an occupancy rates of 11-40%, while few of them had an occupancy percentage above 50% (28%, n=34). Facilities with occupancy rate higher than 50% in low season were due to their location (central facilities) for example Serena Hotels, Serena Lodge and Sopa Wildlife Lodge were due to the efficient booking system, good networking and good customer care. It was indicated that, facility owners in most cases, do consider an occupancy rate above 50% as a breaking-even point and it is when the facility is considered to operate at a profit level.

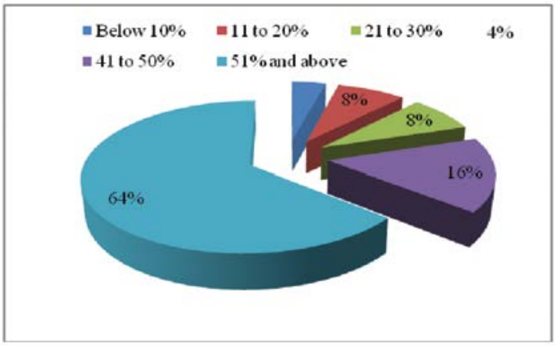

Figure 3: *Facility's occupancy rates in high season*

Accommodation facilities outside the Park

Findings from this study indicated that most of the visitor accommodation facilities outside the park are located in the Western and Eastern Zones. This had might have been associated with the presence of Ikona WMA, investors at Ikorongo- Grumeti Game Reserves (Western) but also Community Based Tourism programmes established around Loliondo GCA where Ololosokwan Village is taken as a model village in the Eastern Zone and Robanda village in Western zone. Existence of the tarmac road joining Mwanza and Mara Regions has significantly contributed to the growing number of visitors who seek accommodation in the Western Zone. Majority of visitors do spend their nights in the hotels adjacent the park which seem to have low costs on transit before visiting SENAPA. It was indicated that, many tour companies from Kenya they normally prefer staying in the lodges outside the park (Western Zone-Lamadi area) before organizing their day trips in SENAPA. Some of these facilities such as Speke's Bay Lodge, Serenity Lodge, Kijereshi Tented Camp, Ndabaka Lodge hotels and camps at Robanda village are of good standard as those facilities that are found inside the park. Facility owners outside the park are now encouraged to construct structures that fits the clients need. Appearance (Plate 1) and management systems adopted is somehow resembling those facilities that are found inside the park, this is done to increase competition among investors. The two zones are far advanced as compared to Southern Zone; as they have much improved roads, airstrip, water availability and improved communication systems. Further it was noted that, the Southern Zone which is less developed in terms of visitor's facilities was seen to be highly visited during the high season in the migration seasons when thousands of wildebeest and zebra are moving in those areas. However, the major challenge is bad roads which are impassable in rain seasons. Accommodation facilities adjacent the SENAPA were noted to operate

Plate 1*: Rooms at Lake Maaseki Tented camp*

at more than 50% occupancy rate in peak seasons. Lake Maaseki Luxury Tented Camp (Plate 2) located in the Southern Zone was indicated to be among the most preferred accommodation facility by visitors due to its higher quality services and unique view, however accessibility by road during the wet season was among the key challenge.

Visitor's experience and satisfaction
Visitor's Experience

A total of two hundred (200) questionnaires were distributed to selected visitor points (Seronera visitor centre, Seronera airstrip and Kogatende airstrip). A total of 134 (67%) visitors responded to the questionnaire, indicating a medium response/return rate. The majority of visitors (85%, n=134) reported to have visited the park for the first time, with few of them having an opportunity of visiting the park more than three times. Majority of respondents aged between 21-65years old. This was related to the reasons that majority of young aged visitors (15-20) probably could not really see the importance of filling the questionnaires as they spent more time for resting or viewing wildlife. Grouping the respondents together, results indicated that, majority of the respondents (70 %, n = 134) were from Europe and North America (Figure 4a), country wise more respondents were from the United States of America (USA) (Figure 4b), findings that is supported from previous studies (Eagles, 2006; Philipo, 2011) followed by United Kingdom (UK). This has an indication that, probably, SENAPA has been highly promoted in UK and USA; therefore, more marketing effort is needed in the new evolving tourism areas specifically in the Asian countries. The main reasons for their visits was indicated to be nature enjoyment (Figure 5a) and majority of them spent two to three nights in the park and others spent even more than 4 days (20%, n=134) (Figure 5b).

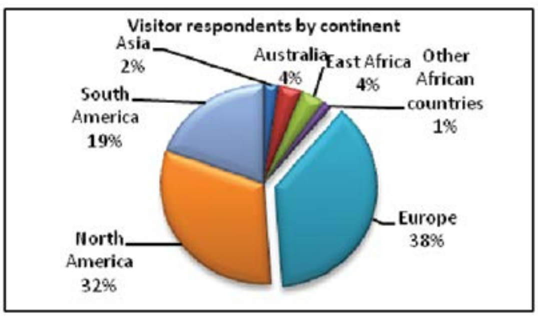

Figure 4a: *Visitors to SENAPA by*

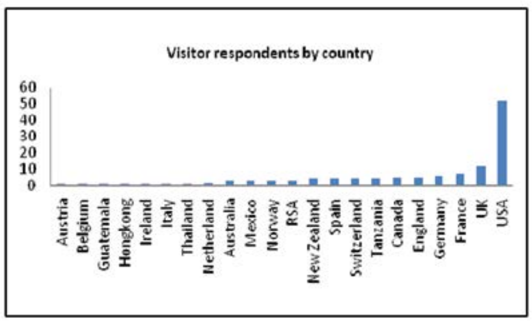

Figure 4b*: Visitors to SENAPA by Country*

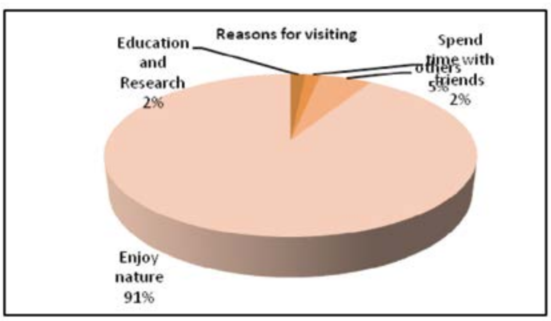

Figure 5a: *Tourists reasons for visiting*

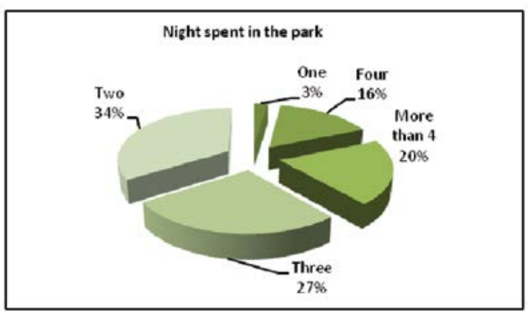

Figure 5b: *Total nights spent in the park*

Visitor's satisfaction

Respondents indicated that the park has tried its level best to meet most of visitor's satisfaction level. Rating some of the facilities and services, a moderate proportion of visitors rated washrooms (toilet) facilities as very good (24%, n=134) and excellent (23%), (Figure 6a). Previous studies in the park had reported poor quality and number of washroom at various visitor meeting points (Eagles, 2006; Philipo, 2011). With this finding, there is an indication that, TANAPA has taken the issue seriously and had renovated most of the toilets at the gates and at camping sites. General rating for accommodation facilities was excellent 52% (N=134), services at the gates (31% excellent), Lodge and Camp Staff services (66% , n=134, excellent), Park staff services (52% excellent) and general quality and health of the park (43% excellent; Figure 6: b-f). Findings on services as indicated in this study are contrary to the previous studies (Eagles, 2006, Kaltenborn *et al*., 2011; Philipo, 2011) who reported existence of poor services from park staff. With these findings there is an indication that, SENAPA Management has started implementing some strategies to improve the services. More efforts are needed especially on the use of modern technologies for communication systems. Among the infrastructures, roads were rated poor (32%, n=134), while the majority 52% (n=134,) did not know of campsite conditions as they did not stay at campsites.

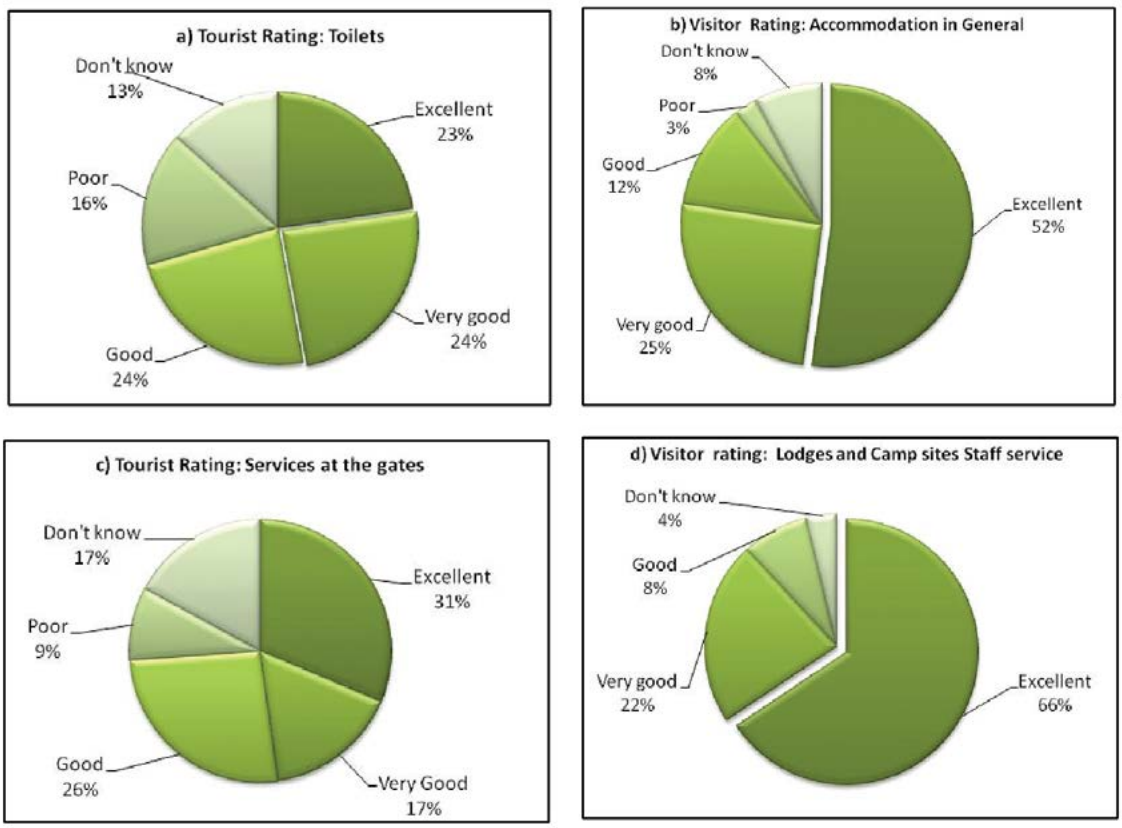

Figure 6(a-f): *Visitors rating on facilities and services in SENAPA*

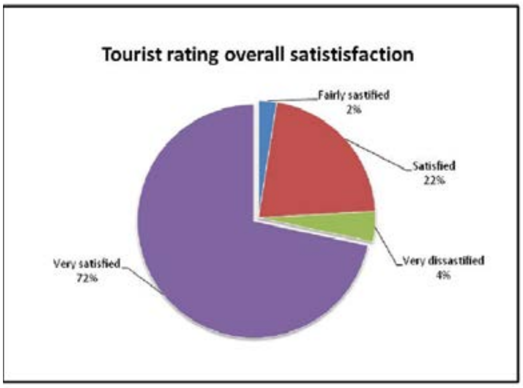

***Figure 7**: Tourists satisfaction in SENAPA*

Overall, majority of visitors were very satisfied 72% (n=134) (Figure 7). The basis for high level of satisfaction was related to the natural and scenic beauty of the SENAPA, good park services, security, existence of the important facilities and diverse wildlife species existing in large Overall, majority of visitors were very satisfied 72% (n=134) (Figure 7). The basis for high level of satisfaction was related to the natural and scenic beauty of the SENAPA, good park services, security, existence of the important facilities and diverse wildlife species existing in large numbers. Similar findings were reported by Eagles (2006) that, 90.4% rated the park as excellent that suggested a high level of satisfaction; this high satisfaction was due to nature of the Serengeti NP. For the minority group (those who were dissatisfied) major reasons were bad roads that to some extent had caused illness, vehicle congestions at Seronera specifically on carnivore sighting points and tsetse flies bites contributed to dissatisfaction level of some visitors.

Ecological threat related to tourists activities in SENAPA

Currently, there is an increasing ecological impacts related to tourist activities that are posing threats to the ecosystem; among others, vehicle congestion at Seronera valley (Plate 3), increased wastes and its mismanagement, sewage disposal problems, blockage of some migratory routes as result of construction of visitors facilities in some key spot areas i.e. at the Kopjes were identified as key ecosystem threats.

It was observed that, construction of some accommodation facilities did not follow conservation priorities and targets as indicated in the GMP. Some facilities have been constructed closer to the Mara River bank and others on Kopjes. This was due to conflict of interest between investors and park management; while investor's were looking for the excellent views, SENAPA is towards sustainable conservation of resources. In this case, the interest of management authorities should be given a priority, and this can be achieved by respecting the GMP by all stakeholders including policy makers.

Furthermore finding showed that majority of visitors were attracted by the natural environment of the park with diverse wildlife species, therefore, any kind of habitat destruction may lead to reduction of the number of visitors due to low visitor satisfaction. With this regard is therefore important to ensure that, while plans in the SENAPA GMP is to increase number of visitor facilities by 2024 but the consideration on habitat quality and the visitor's satisfactions are also key issues to be considered beforehand. Any major change that will affect the Serengeti ecosystem will directly reduce the number of visitors into the park, which consequently may affect the financial flow of the park and GDP of the country at large.

It is important to note that, TANAPA should thus continue with its plans as stipulated in the integrated National Tourism plan of 2002 on advocating and for developing tourism product that will attract low-volume but high yield international tourism market which basically support the Low Density high quality model that was suggested by Howerton and Sinclair 2007. Tourism being the world's largest industry is all about selling visitor's experiences. Like in many other tourism destinations (Buhalis, 2000), selling of high quality visitor products should be a primary objective. All over the world, majority of tourists travel to far distances to enjoy the nature (Plessis et al. 2012). A learning experience by Laven et al. (2005) indicated that, when tourists perceive that the quality of the environment does no longer meet their expectations due to ecological impacts related to tourism activities, they may either adjust their standards of quality to match the existing state of the environment or they may go elsewhere. That, tourists will be displaced i.e. will no longer visit that particular park which could result to decline in revenue (Plessis et al. 2012).

A comparison has been made by different stakeholders by trying to compare SENAPA and Maasai Mara National Reserve in Kenya with its high capacity of beds. However, an analysis done by Howerton and Sinclair in 2007 indicated that, the advocacy on mass tourism on Kenyan side has severely affected Maasai-Mara National Reserve. Mushroom of hotels and lodges, with increased number of vehicles in the reserve has resulted into loss and destruction of wildlife habitats (MMNR,2009). It was noted that, resident wildlife populations declined to over 70% percent between 1980 and 2002 inside and outside the Masai Mara National Reserve (Bhandari, 2014). Despite the higher number of visitors in Kenya, still revenue collected was less as compared to Tanzania the reason for that was related to the fact that, time spent by tourists in Tanzania was higher due to diverse attractions and packages as compared to areas that were visited in Kenya. This is an indication that, presence of many beds, may not necessarily contribute to high income, but a combination of other factors.

CONCLUSION AND RECOMMENDATIONS

Despite the fact that SENAPA appears to have adequate accommodation facilities per night, the only concern is unequal distribution of accommodation facilities and uneven distribution of visitor needs/ requirements and attraction sites in the park. While there are more accommodation facilities in the Central Zone, other zones have very few accommodation facilities. In this regard, there should be a more or less equal distribution of visitor facilities in all zones and the study recommends for putting one more lodge in the south-eastern and one in the western zone to accommodate more tourists in high season, however the type of lodge to be constructed should relate to visitor's preferences and also should reflect the ecological integrity of the park. Also addition of more accommodation facilities in other zones should be coupled with improvement of other visitor infrastructures including roads and basic needs for park staff and tour drivers like petrol stations, cheep accommodation facilities, shops/curios, communication system, visitor centre, recreation centres, health centres etc).

Over all SENAPA has tried to meet most of visitors' satisfaction level. Majority of visitors who were interviewed were very satisfied with it was observed that, SENAPA had done some important improvement based on previous recommendations, facilities such as toilets at the gates and at camping sites have been improved with increased efforts to build staff capacity at the gates. However there is still a need to improve other areas including training of staff (both park and tourist facilities) on customer care.

Despite the good improvements, still there are some factors that were identified as obstacles to the tourism business in the park. Bad roads, tsetse flies, poor network system that causes delays at the entrance gates, inadequate facilities and services at the airstrips and poor customer care services resulted into dissatisfactions to some visitors. It is therefore, imperative for SENAPA puts emphasis on addressing these obstacles in order to increase visitor satisfaction and tourism experience in the park.

The study also conclude by recommending that addition of accommodation facilities in the park is not the only solution for bringing more tourists and increase tourism revenue; there other factors that if well addressed, managed and improved could significantly increase revenue from tourists with less environmental impacts. Thus, increasing accommodation facilities while forgetting key ecological impacts associated with increased number of facilities and visitors.

It is also important to note that most of the accommodation facilities do not belong to TANAPA they are owned by private companies. This makes SENAPA to suffer double impacts; one being limited control on the quality of facilities and their services, and secondly is that SENAPA is depending much on gate fees as the main source of revenue while it would have accrued more if some of the facilities would have been owned by SENAPA. Thus, in any plan for adding accommodation facilities, other zones (South, East and west) should be given a priority and it should be coupled with improvement of other visitor infrastructures including roads and basic needs for park staff and tour drivers like, petrol stations, cheep accommodation facilities, shops, communication system, visitors centre, recreation and health centres. Furthermore, an idea of SENAPA having a plan to own few accommodation facilities should be given a priority.

The study also noticed a lack of unique international tourism brand for the specialties and uniqueness of Serengeti, Management authorities thus, should not only concentrate on additional of accommodation facilities as a means to increase revenue from tourism, but should also focus and give more priority on developing and promoting the national tourism branding that will include the uniqueness of its rich tourism attractions of which Serengeti is among the most important hotspot area.

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PASTORALIST HERDING EFFICIENCY IN DEALING WITH CARNIVORE - LIVESTOCK CONFLICTS IN THE EASTERN SERENGETI, TANZANIA

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ABSTRACT

Wild carnivores are often involved in conflicts with humans due to their predation on livestock. We investigated the herding efficiency of pastoralists in association with depredation on livestock in the Loliondo game-controlled area (LGCA), northern Tanzania, to identify specific herding practices that may reduce predation occurrence. Randomized face-to-face interviews were employed using semi-structured questionnaires. Our results indicate that all studied livestock herds were tended to by at least one herder. Despite the presence of herders, carnivores were found to attack livestock in half of the observed herds. Female herders experienced more attacks than male herders. African wild dogs and spotted hyenas most frequently attacked the livestock of the Sonjo tribe, whereas leopards and lions most frequently attacked livestock of the Maasai tribe. Herders carrying defensive equipment (knives and spears) reduced the number of successful carnivore attacks in the area. We recommend maintaining and improving the traditional livestock husbandry practices of using herders to reduce carnivore attacks. Moreover, increasing the number of adult male herders per herd and carrying gear might also help reduce such attacks. Using herders can potentially improve economic gains and livelihoods of local people and change their negative attitudes towards wild carnivores.

Key words: *Carnivore species, depredation, livestock herding, human-wildlife conflict, Serengeti.*

INTRODUCTION

Wild carnivores play an important role in ecosystem functions and are often a major attraction for tourists and thus an important source of revenue for many protected areas in developing countries (Durant et al., 2011a). Despite such important ecosystem function, most wild carnivores have been found to be in conflict with humans, especially when they prey on livestock (Jackson *et al.,* 1996; Kaczensky, 1999; Woodroffe *et al.,* 2005; Ikanda & Packer, 2008; Larson, 2008) or attack people (Packer et al., 2005; Kaltenborn et al., 2006; Dickman, 2010). Human-carnivore conflict over livestock predation has been reported to be a major obstacle for conserving large carnivore species, in particular in the Serengeti ecosystem (Jackson et al., 1996; Kaczensky, 1999; Woodroffe et al., 2005; Ikanda and Packer, 2008; Larson, 2008). Thus, this conflict poses many challenges in enhancing the conservation and management of large carnivore species (e.g., lions (*Panthera leo*), leopards (*Panthera pardus*), cheetah (*Acinonyx jubatus*), spotted hyenas (*Crocuta crocuta*) and African wild dogs (*Lycaon pictus*) in the Serengeti ecosystem (Holmern *et al.,* 2007; Ikanda and Packer, 2008; Masenga et al., 2013; Lyamuya *et al.,* 2014a). This challenge arises due to the economic cost caused on the side of the livestock keeper by these carnivores, such as the reduction of income expected from livestock sales (Woodroffe *et al.,* 2005; Holmern *et al.,* 2007; Nyahongo, 2007), which eventually increases poverty and hunger within the society. In comparing with domestic animals wchih have direct benefits to households socially and communities under this study have a low tolerance for the depredation behaviour of large carnivores (Holmern *et al.,* 2007; Nyahongo, 2007; Ikanda & Packer, 2008; Masenga *et al*., 2013). To prevent this depredation, most livestock owners, in retaliate by killing large carnivore species that prey on their livestock (Nyahongo, 2007; Ikanda & Packer, 2008; Masenga *et al*., 2013). Such killing is one of the factors that lead to population decline of these predators (Kolowski &Holekamp, 2006; Holmern *et al.,* 2007; Kissui, 2008; Masenga *et al.,* 2013). Some of the carnivore species have even suffered local extinction in their former range as a result of such a conflict, such as African wild dogs as also reported elsewhere (Swarner, 2004; Woodroffe et al., 2005; Woodroffe *et al.,* 2007).

One of the main factors associated with this problem is the increase in the human population, which eventually leads to increased land conversion for agriculture and human settlements, thus reducing the service provided by the ecosystems as well as a loss of natural habitats for large carnivores (Msuha, 2009). Moreover, the increased hunting of wild herbivore species by humans for either subsistence, sport or trophies has led to the depletion of wild prey species needed by large carnivores (Wang & Macdonald, 2006; Mwebi, 2007). In addition, a large home range requirement for most large carnivores forces them to overlap with human activities outside protected areas, increasing conflict with farmers (Larson, 2008). Some attempts have been made to reduce livestock depredation, including problem animal control, problem animal translocation and herding practices (Mwebi, 2007; Woodroffe *et al.,* 2007).

Several studies have revealed that livestock depredation occurs at night (Maddox, 2003; Holmern *et al.,* 2007; Nyahongo, 2007; Ikanda & Packer, 2008; Mwakatobe *et al.,* 2013; Lyamuya et al., 2014b) but also during the day (Ikanda & Packer, 2008; Lyamuya *et al.,* 2014b) in the Serengeti ecosystem. Temporal differences in the occurrences of these depredation events in the area depend very much on the behaviour of the carnivore in question (Woodroffe et al., 2005; Kissui, 2008). Some of the large carnivores are diurnal in nature and thus hunt or prey on livestock only during the day, such as the African wild dog and the cheetah (Maddox, 2003; Lyamuya *et al.,* 2014a), while others are both diurnal and nocturnal, such as lions (Ikanda and Packer, 2008; Kissui, 2008). Other large carnivores, such as spotted hyenas and leopards, are mostly nocturnal (Holmern *et al.,* 2007; Nyahongo, 2007; Ikanda & Packer, 2008; Kissui, 2008; Lyamuya *et al*., 2014a). Therefore, most livestock depredation reportedly occurs during the night in the north-western Serengeti ecosystem (Holmern *et al*., 2007; Nyahongo, 2007; *Mwakatobe et al.,* 2013), southern Serengeti ecosystem (Ikanda & Packer, 2008) and eastern Serengeti ecosystem (Maddox, 2003). Spotted hyenas and leopards were the main predators in the northern Serengeti ecosystem, likely because the populations of spotted hyenas and leopards are larger in that part of the ecosystem (Holmern *et al.*, 2007). However, depredation in the Loliondo Game Controlled Area (LGCA) surprisingly occurs during the day. This daytime depredation is likely due to wild dogs. Although wild dogs were reported extinct in the Serengeti ecosystem in the 1990s (Stearns & Stearns, 1999), a few individuals were recently found to have remained unnoticed in the LGCA (Marsden *et al*., 2012). These remaining individuals have had enough to eat and did not prey on livestock. Wild dogs normally prefer to hunt or prey on wild prey species over livestock when wild prey species are abundant (Rasmussen, 1999; Woodroffe *et al*., 2005; Gusset *et al.,* 2009). However, though wild dog population has increased in the area since 2000 (Masenga & Mentzel, 2005; Masenga, 2010) that of their prey species have significantly lower densities when compared with those found within the National Park (Rusch *et al*., 2005). Therefore, wild dog predation on livestock has increased in that area over the last decades (Holmern *et al*., 2007; Lyamuya *et al*., 2014a). Lyamuya *et al*.,(2014a) found that wild dogs were the most common predator of livestock in the LGCA. However, wild dogs have never been found to prey on livestock while livestock are kept in their enclosures (i.e., bomas) (Woodroffe *et al*., 2005; Holmern *et al*., 2007; Lyamuya *et al*., 2014a).

In general, the methods used to protect livestock from wild predators do not differ very much within the Serengeti ecosystem (Maddox, 2003; Holmern *et al.*, 2007; Nyahongo, 2007; Ikanda & Packer, 2008; Mwakatobe *et al*., 2013). Most livestock keepers in the area apply traditional livestock husbandry practises such as the use herders to herd their livestock during the day while they are out in the grazing fields (Holmern *et al*., 2007; Nyahongo, 2007; Ikanda and Packer, 2008), while they employ enclosures (i.e., bomas) during the night to keep their livestock safe (Holmern *et al.,* 2007; Nyahongo, 2007; Ikanda & Packer, 2008; Mwakatobe *et al.*, 2013). During the daytime, the incidence livestock attacks by predators are low when the livestock herds are small and accompanied by the herders and their dogs (Woodroffe *et al*., 2007). During the night, the risk of attacks is lowest for herds held in enclosures ("bomas") with dense walls and pierced by a few gates, where both humans and domestic dogs are present (Woodroffe *et al*., 2007; Gusset *et al.*, 2009). This traditional livestock husbandry practise of using herders has been applied since ancient times (Wang & Macdonald, 2006; Mwebi, 2007; Woodroffe *et al*., 2007). However, little is known about the efficiency of using such herders in reducing depredation (Fratkin, 2001; Galvin *et al*., 2004; Mwebi, 2007; Fauvelle-Aymar & Sadr, 2008; Kirkbride & Grahn, 2008; Johannesen & Skonhoft, 2011; Grillo, 2012) as well enhancing their coexistence in the area.

This study investigated why wild dogs prey more frequently on livestock during the day, as discovered in a previous study (Lyamuya *et al.*, 2014a) to propose appropriate solutions to the problem, thus reducing retaliatory killing of this species (Masenga *et al.*, 2013).This will enhance their coexistence on one hand while on the other hand it will improve ecological services accrued from the biodiversity found in the area.Specifically, we will discuss whether leaving livestock herds unattended in the grazing field or the abandoning of traditional husbandry techniques results in increased predation. Moreover, we will discuss methods to reduce this predation problem and enhance coexistence. To obtain this information, we hypothesised 1) that adult male herders are more efficient in caring for livestock than females because males, but not females, in both the Maasai and Sonjo cultures receive general training which involves fighting against dangerous wild animals and other enemies before they become "Morans" (warriors) (Mwebi, 2007; Budgor, 2014). In addition, we hypothesised 2) that the Maasai tribe suffers more losses of livestock to carnivores than the Sonjo tribe, as they remain closer to the park boundary where the carnivore populations densities are higher (Maddox, 2003; Durant *et al.,* 2011a) and livestock depredation events increases as the distance from the park boundary decreases (Holmern *et al*., 2007; Nyahongo, 2007; Mwakatobe *et al*., 2013). 3) We hypothesized that the use of equipments as spears and knives as well as guarding dogs will reduce carnivore depredation. We finally hypothesised 4) that livestock predation will occur more frequently in herds herded by one herder than those herded by several herders.

METHODS

Study Area

The study was conducted in the eastern Serengeti ecosystem, which includes the Loliondo Game Controlled Area (LGCA) and Ngorongoro Conservation Area (NCA) (Fig. 1). The Maasai and Sonjo tribes inhabit these areas. The Maasai are nomadic pastoralists with very few agro-pastoralists, whereas the Sonjo are sedentary agro-pastoralists (Masenga and Mentzel, 2005; Masenga, 2010; Lyamuya, 2011). Therefore, the Maasai depend entirely on livestock for their economic gain. The Sonjo people do keep livestock, but they do not depend entirely on it, as they are also engaged in other economic activities, such as crop cultivation and other small retail businesses.

The LGCA is located in the Maasai ancestral land in the northern part of Tanzania along the Kenyan border. It is a game controlled area where human activities are allowed and forms the eastern boundary of the Serengeti ecosystem. It borders the Ngorongoro highlands to the south, Serengeti National Park (SNP) to the west and Lake Natron to the east. It encompasses an estimated area of approximately 4500 km². No physical barrier separates the LGCA from other parts of the ecosystem. Thus, animals move freely within the ecosystem. The human population, which was estimated to reach 160,925 people in 2012 (URT, 2013), increases from south to north, with the highest densities around Wasso, Loliondo town and the areas near the Kenyan border (Masenga and Mentzel, 2005). In the south, a few nomadic Maasai have settled at a low density.

The climate of the study area is mostly influenced by the Ngorongoro crater highlands, which creates a rain shadow and the hydrologic cycles of Lake Victoria and cause temperature fluctuations between the lake and the surroundings (Jaeger, 1982). The area exhibits a bi-modal rainfall pattern, with peaks occurring in December and April and a total of 400-1200 mm rain per annum (Masenga and Mentzel, 2005; Lyamuya, 2011). The area is dominated by open woodland and grassland. Open woodland is found mostly in the northern part on the rolling hills, interspersed with rocky outcrops. The central part includes mountains with steep slopes and densely vegetated gullies. The open areas in the lowlands are either cultivated or open woodland areas. The south portion of the area gives way to short grassland. The Government of Tanzania, through the Ministry of Natural Resources and Tourism (MNRT), formed the Wildlife Policy of Tanzania in 1998 to increase the role of local communities in managing and benefiting from wildlife on village lands, in particular in the LGCA (Stolla, 2005). Community involvement has increased via forming Wildlife Management Areas (WMA) to implement this policy (Stolla, 2005).

Data collection

The data were collected from July to August 2010. Randomised face to face interviews using semi-structured questionnaires were employed together with information from the herders in the field. Six villages were randomly selected from each tribe for data collection. In each village, 30 livestock herders (cattle/donkey and or goats/sheep), each representing one household, were randomly selected in the grazing fields based on recommended sample size (Sancheti and Kapoor, 2003). However, all herders could not be reached due to the difficult terrains in the Sonjo area; therefore, this study includes fewer respondents from this tribe (*n* = 72) compared to the Maasai tribe (*n* = 212).The researchers drove randomly in the herding fields during the day, and the first herd encountered was followed to check for the presence of the herder. Once the herder was discovered, the following data were collected prior to the interview: the number of herders, age and sex of the herder, and herding equipment (equipment were pooled into four categories: 1 = nothing, 2 = sticks or clubs, 3 = spears or knives, and 4 = the presence of domestic dogs in addition to any of the other weapons). Moreover, the numbers of cattle and sheep/goats were determined via direct counting. To familiarise ourselves with the herder, a trained enumerator from their own tribe was the first to exit the car and introduce us to him/her and explained the purpose of our visit. The herder was asked to respond to a variety of questions to fulfil the purposes of research. The information required from the herder was his/her age, gender, if his/her livestock had been attacked by any wild carnivores in the last two months while out grazing (yes or no), which wild animals were involved in the attack, how many livestock were killed, which livestock species was killed, and how many of them were killed in the last two months.

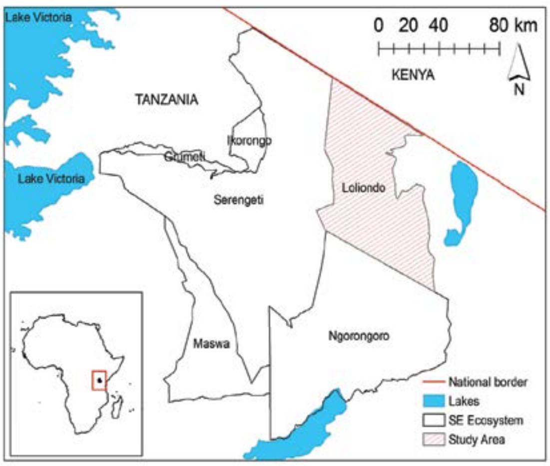

***Figure 1**: Study area*

Data Analyses

Because most of our data were nominal, non-parametric statistical tests were performed for this study (Fowler et al., 2009; Zar, 2010). To gain insight into the pastoralist herding efficiency we mostly used chi-square tests to determine differences in how herders responded to the question "Have your livestock been attacked by any wild carnivore species over the last two months when you were herding them?" In addition, the test was used to determine differences in the frequencies of attacks by wild carnivores and differences between age classes (young (3-14 years), youth (15-30 years), adults (31-45 years), and elders(> 45 years), gender (males, females) and equipment used (no equipment, club-stick, knife-spear, domestic dog) to herd livestock. Furthermore, one-way ANOVA tests were used (after testing the data on the numbers of killed livestock by one-sample Kolmogorov-Smirnov Test and found their distribution is normal) to determine the differences between the numbers of killed cattle/donkey and sheep/goats and their mean number in the herds.

To determine the factors responsible for livestock loss in the area, a binary logistic regression test with livestock attacks as a dependent variable (yes, no) and tribe, gender, age group, number of herders, herd size and herding equipment as independent variables. For all tests, $p \leq 0.05$ was considered significant, and leopards and lions were pooled together in some statistical analyses because of their low numbers. The Statistical Package for Social Science (SPSS) Statistics version 20.0 for Windows (SPSS, 2011) was used to perform all analyses (Kirkpatrick and Feeney, 2010).

RESULTS

Tribe

All livestock herds (100%, n = 284) were attended by at least one herder (1 herder = 88.7%, 2 herders = 9.2%, > 3 herders = 2.1%). More than 50% (55.2%, N = 252) of herds tended with one herder had experienced attacks by large carnivores while only 9.4% (N = 32) of herds with more than one herder had experienced attacks by wild carnivores (χ^2 = 23.8, df = 1, p < 0.001). However, only 50% of the groups had experienced livestock attacks (*n* = 284) by wild carnivores during the two months preceding the survey. The Maasai herders responded "yes" significantly more frequently (55.2%, *n* = 212) than Sonjo herders (34.7%, *n* = 72) when asked if their livestock had been attacked by wild carnivores (χ^2 = 8.20, df = 1, $p < 0.01$).

In 83 cases, (58.5%, *n* = 142) at least one domestic animal was killed both among the Maasai (59.8%) and Sonjo (52.0%) herders when attacked by wild carnivores, whereas 11.3% (*n* = 16) cases ended in the death of cattle and 47.2% (*n* = 67) cases ended in the death of sheep/goats. No difference in terms of killed livestock between the two tribes was found (χ^2 = 0.247, df = 1, p = 0.619). In addition, no difference was found between the two tribes (ANOVA F = 1.247, p = 0.266; and F = 0.996, p = 0.455) in cases wh

Large herd sizes (101-500 individuals) experienced most attacks by wild carnivores (60.5%, *n* = 119) followed by medium sized herds (51-100 individuals; 50%, *n* = 26, attacked), while the small-sized herds (2-50 individuals; 39.2%, *n* = 97) and very large herds (>500 individuals, 40.0%, *n* = 15) were infrequently attacked (χ^2 = 10.4, df = 3, p = 0.015). In addition, very large and large herds (62.6%, *n* = 211) were more frequently found in the Maasai than in the Sonjo (2.8%, *n* = 72) tribe (χ^2 = 105.1, df = 3, $p < 0.0001$). Almost 42% (41.1%, *n* = 142) of the attacks by wild carnivores resulted in no livestock being killed, while one livestock was killed in 18.3% of the attacks, and 40.2% of the attacks resulted in that two or more livestock were killed. However, no difference in numbers (0, 1, >1) of livestock killed was found between the two tribes (χ^2 -test, p = 0.611), or between the different herd sizes (χ^2 -test, p = 0.716*)*.

Table 1: Differences in number of livestock (killed and herded number of cattle and sheep/goats) between the two tribes during the over two months study in the Loliondo Game Controlled Area during the 2010 survey.

	Maasai			Sonjo		
	Mean	SD	N	Mean	SD	N
Livestock killed*	2.2	0.9	70	1.9	0.9	13
Livestock killed**	1.3	1.3	117	1.0	1.2	25
Cattle per herd	129	201	212	18	21	72
Sheep/ goats per herd	254	379	212	28	27	72

*Only when at least one livestock animal was killed.
**including all cases of attacks (also when no livestock was killed)

Carnivore species

African wild dogs and spotted hyenas most frequently attacked livestock of the Sonjo tribe, whereas leopards and lions attacked livestock most frequently in the MaasaiThe numbers of both cattle and sheep/goats in the herds were significantly higher among the Maasai than among the Sonjo herders (cattle; ANOVA F = 21.7, $p < 0.0001$; sheep/goats; F = 25.6, $p < 0.0001$; Table 1). However, the number of herders did not differ between the two tribes ($\chi^2 = 0.147$, df = 1, $p = 0.702$). tribe (Table 2). The frequency of killed livestock was highest (84.6%) when attacked by other carnivores (cheetah, black backed jackals (*Canis mesomelas*) and baboons (*Papio cynocephalus*)) and lowest (47.6%) when attacked by wild dogs (Table 2). However, this difference was not significant ($\chi^2 = 0.029$, df = 3, $p = 0.103$; Table 2). As a consequence, more livestock was killed when attacked by other carnivores (ANOVA F = 4.02, $p = 0.009$; Table 2). Finally, the frequency of attacks that resulted in killed cattle or sheep/goats among the carnivore species did not significantly differ ($\chi^2 = 11.1$, df = 3, $p = 0.084$; Table 2).

Gender

The frequency of carnivore attacks was significantly higher when females (62.5%, $n = 64$) rather than males (46.4%, $n = 220$) Nevertheless, the number of herders did not differ significantly by gender ($\chi^2 = 1.7$, df = 3, $p = 0.619$). Furthermore, males attended significantly larger livestock herds (333 ± 529 SD) than females (171 ± 252 SD) (log transformed ANOVA $F = 11.1$, $p < 0.001$). However, the loss by female herders (1.1 ± 1.3 animals per attack) did not differ significantly from than that of male herders (1.3 ± 1.2 animals per attack; ANOVA $F = 0.585$, $p = 0.445$).

Age class

The attack rates did not differ significantly by age class (ANOVA $F = 0.089$, $p = 0.966$). In addition, number of herders did not differ significantly with the age class ($\chi^2 = 7.42$, df = 9, $p = 0.593$). In general, single herders were more frequently adults (90.9%) and young (90.8%) than youth (86.4%) or elders (75.0%).

Equipment

Carrying equipment (e.g., knife/spear) as a defence did not differ between the two gender (χ^2 -test; p=0.381), or between different age classes (χ^2 -test; $p = 0.300$). However, the frequency of carnivore attacks differed significantly by the equipment used

Table 2: Carnivore species involved in attacks on livestock in relation to tribe (Maasai, Sonjo), frequencies (in %) of killed livestock and number of livestock killed per attack (zeroes included; ANOVA and χ^2 tests of differences).

	Frequency of killed livestock			Number of killed livestock		
Tribe	Maasai N attacks	Sonjo N attacks	%	N	Mean	SD
Other carnivores*	11	2	84.6	13	2.2	1.1
Leopards/Lions	44	2	56.5	46	1.1	1.2
Hyenas	31	10	63.4	41	1.5	1.3
Wild dogs	31	11	47.6	42	0.9	1.1

*Cheetah, black backed jackals, baboons

by herders ($\chi^2 = 75.3$, df = 3, $p < 0.0001$; Table 3). The lowest attack rate was found among herders that protected their livestock with knives or spears (17.1%; Table 3) compared with the three other groups (Table 3).

Although the frequencies of attacks that ultimately resulted in livestock death did not differ between the two tribes, the frequency of using different weapons differed significantly between the two tribes ($\chi^2 = 27.2$, df = 3, $p < 0.0001$; Table 4).

Table 3: Frequencies of answers (yes or no) from herders to the question "Have your livestock been attacked by any wild carnivore species in the last two months when you were herding them?" in relation to the herding equipment they were using (Number of herder responses, with percentages in brackets; difference was tested with a Chi square test).

Answer	No equipment	Club-stick	Knife-spear	Domestic dog
	N (%)	N (%)	N (%)	N (%)
Yes	23 (79.3)	83 (70.3)	18 (17.1)	18 (56.2)
No	6 (20.7)	35 (29.7)	87 (82.9)	14 (43.8)
Total	29 (100)	118 (100)	105 (100)	32 (100)

Table 4: Numbers of male and female herders with or without herding equipment between the two tribes who answered yes to the question "Have your livestock been attacked by any wild carnivore species in the last two months when herding?" (Number of males and females herders responded, with percentages in brackets; difference was tested with a Chi square test).

Herding equipment	Tribe	
	Maasai N (%)	Sonjo N (%)
No equipment	25 (11.8)	4 (5.6)
Club-stick	99 (46.7)	19 (26.4)
Bush knife-spear	60 (28.3)	45 (62.5)
Domestic dog	28 (13.2)	4 (5.6)
Total	212 (100)	72 (100)

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	Frequency of killed livestock		Number of killed livestock			
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*Cheetah, black backed jackals, baboons

were herding the livestock (χ^2 = 5.16, df = 1, p = 0.023). The Maasai tribe used male herders more often (82.5%, n = 212) than did the Sonjo tribe (62.5%, n = 72; χ^2 = 12.4, df = 1, p < 0.0001).

A logistic regression test with livestock attacks (yes or no) as a dependent variable proved that herding equipment (B = 0.739, Wald = 19.38, df = 1, p < 0.0001), herd size (log-transformed) (B = -0.763, Wald = 10.56, df = 1, p = 0.001), gender (B = -0.843, Wald = 6.46, df = 1, p = 0.011), and number of herders (B = 1.080, Wald = 5.92, df = 1, p = 0.015) were all significant independent variables in explaining the attack rates (χ^2 = 55.90, df = 4, p < 0.0001, Nagelkerke r^2 = 0.239). Age class and tribe did not add any significant value in explaining this variation.

DISCUSSION

Tribe

This study revealed that all livestock herds visited during the day out in the field between both the Maasai and Sonjo tribes were attended by at least one herder. The use of herders is an ancient traditional livestock husbandry practice used by many pastoralist societies worldwide to move their livestock to good pastures and areas containing sufficient water (Galvin *et al*., 2004; Mwebi, 2007; Grillo, 2012; Little *et al*., 2012) and also later on were used as a means to reduce livestock loss through depredation (Johannesen and Skonhoft, 2011; Little *et al*., 2012) as well as theft (Nyahongo 2007). According to Ogada *et al*., (2003) livestock husbandry, similar to that practiced for generations by local Masai and Sonjo pastoralists, was very effective at reducing conflict between predators and livestock farmers. Therefore it improves tolerance and thus builds up positive attitudes towards wild carnivores' conservation wherever they coexist (Ogada *et al.*, 2003; Mwebi, 2007; Woodroffe *et al*., 2007). Since our survey was carried throughout the day, it was clear that the herders from both tribes spent more time with their livestock in the field as found in the previous studies and thus less livestock depredation was expected to occur (Ogada *et al*., 2003; Woodroffe *et al*., 2007). This was because the use of herders is a time-tested tradition that had proved successfully in alleviating predation (Gese, 2003). In addition, the use of herders was an indication that both the Maasai and Sonjo tribes used grazing lands daily to feed their livestock by accessing the services from natural resources in the Serengeti ecosystem (Kideghesho, 2010; Schmitt, 2010). Therefore, this access improves their livelihoods and thus enhances the conservation goals of the area.

On the other hand, though both the Maasai and Sonjo tribes use herders, half of them reported that they had experienced livestock attacks by wild carnivores in the preceding two months. Furthermore, the Maasai herders reported to suffer more attacks from wild carnivores than did the Sonjo herders. Therefore supported our hypothesis that the Maasai tribe suffers more losses of livestock to carnivores than the Sonjo tribe, as they remain closer to the park boundary (Lyamuya *et al*., 2014) where the carnivore populations densities are higher (Maddox, 2003; Durant et al., 2011a) and since previous studies found that livestock depredation events increases as the distance from the park boundary decreases (Holmern *et al*., 2007; Nyahongo, 2007; Mwakatobe *et al*., 2013).

In addition, the Maasai tribe used single herders more frequently than the Sonjo tribe, which is another reason for the increased frequency of attacks. This finding also supported our hypothesis that livestock predation will occur more frequently on herds herded by one herder than those herded by several herders. However, herders were only able to prevent the killing in approximately 40% of the carnivore attacks. In those attacks, sheep/goat were more frequently killed than cattle, most likely because most of the attacks were by carnivore species other than lions (Ikanda & Packer, 2008).

As the result, according to the theory of reason action (Ajzen & Fishbein, 1980) such attacks by wild carnivores would create negative attitudes among the Maasai and Sonjo tribes towards conservation of large carnivores in their areas. This because in most cases it has been found that, humans behave negatively towards large carnivores when kill their livestock or attack people (Løe & Røskaft, 2004; Lagendijk & Gusset, 2008; Yirga *et al*., 2011; Carter *et al*., 2014; Lyamuya *et al*., 2014a) and as the result large carnivores are the ones to suffer as the consequence of such attitudes which usually undermine their management and conservation efforts (Ikanda & Packer, 2008; Kissui, 2008; Yirga *et al*., 2011; Masenga *et al*., 2013; Carter *et al*., 2014). Hence, the use of herders improves economic gains and livelihoods of local people as well as it may change their negative attitudes (Woodroffe *et al*., 2007).

Furthermore, the numbers of both cattle and sheep/goat in the herds were significantly higher in the Maasai than in the Sonjo areas because the former are pastoralists and therefore keep large livestock herds as insurance against adverse environmental conditions that might cause loss, which is corroborated by previous reports (Galvin *et al*., 2004; Johannesen & Skonhoft, 2011; Little *et al*., 2012). Despite this difference, the average number of livestock killed per attack did not differ between the two tribes or in different sized herds. This could be attributed to the fewer sample sizes obtained from Sonjo tribe than those from the Masaai tribe because the former lives in highland areas separated by more hills/ mountains nearby which reduced herders visibility than the later who mostly lives on lowland areas with fewer hills/mountains nearby.

Carnivore species

Our results also revealed that a variety of carnivore species attacked the livestock, although more carnivore species were involved in the Maasai area. This finding is attributed to the fact that the Maasai tribe stays closer to the park boundary, where the density of wild carnivores species is higher (Maddox, 2003; Durant *et al*., 2011a) than in the area inhabited by the Sonjo tribe (Lyamuya *et al*., 2014a). This high amount of reported livestock attacks might put the conservation status of large carnivores in danger in the area (Lyamuya *et al*., 2014a). Since previous studies have found that livestock depredation is among the main reason for most pastoralist communities not supporting large carnivores conservation (Ikanda & Packer, 2008; Kissui, 2008; Masenga *et al*., 2013). In addition, medium sized carnivore species more frequently attacked livestock in the Maasai than in the Sonjo area, most likely because the Maasai herders keep a higher number of goats/ sheep than the Sonjo, which increases the chances of depredation (Lyamuya *et al*., 2014a). In addition, medium sized carnivores more frequently killed livestock than did large carnivore species because they prey on sheep/goats, which are easier to hunt and kill than cattle. Furthermore, leopards and lions were responsible for more attacks in the Maasai than in the Sonjo areas. The densities of these animals are higher near the park boundary (Maddox, 2003; Durant *et al.*, 2011a); thus, they were responsible for more incursions against the Maasai than the Sonjo tribe (Holdo *et al*., 2010; Lyamuya *et al.*, 2014a). Conversely, African wild dogs and spotted hyenas were most frequently responsible for attacking the livestock in the Sonjo area. African wild dogs attacked the Sonjo tribe more than any other carnivore species because they are the most common carnivore species found in that area. This species is the dominant carnivore species in human-dominated landscapes in the Loliondo area (Lyamuya *et al.*, 2014a). Our study investigated herding efficiency throughout the day from morning hours to the evening hours were most of the livestock depredation were reported to occur by this species in the area (Lyamuya *et al*., 2014a) to understand what is happening during these herding hours in the field.

Age and Gender

Moreover, reported attacks by large carnivores were significantly more frequent when females were the herders. This finding concur with our hypothesis that adult male herders are more efficient in caring for livestock than females because males, but not females, in the Maasai and Sonjo cultures receive general training which involves fighting against dangerous wild animals and other enemies before they become “Morans” (warriors) (Mwebi, 2007; Budgor, 2014). Therefore, they have more defensive training than females when trusted to herd livestock in the field. Furthermore, this finding might be of importance to the conservation of large carnivores as, according to Marchini and Macdonald (2012), in their theory of planned behavior, female herders as a result of incurred costs from livestock depredation might pass their negativity attitudes in disfavor of large carnivore conservation to their husbands and children, hence they may jeopardize such coexistence. Despite of that female herders have also been found in other studies, e.g. in Peru, where herders are girls rather than boys (Van den Berge, 2009; FAO, 2013). Within the livestock sector, herding appears to be an important activity that involves child labour (FAO, 2013).

However, the loss by female herders when attacked was not higher than that of male herders in our study, most likely because female herders were fewer than the male herders in the area. A study by the FAO (2013) found that males were generally more involved in herding activities than females, which agrees with our findings. Our results revealed that very few female herders were found in groups of two, three or four in both tribes. Furthermore, the Maasai tribe used more male herders in proportion to females than the Sonjo tribe, most likely because of the division of labour within the Maasai society directs young male Maasai to herd their livestock, while females perform other domestic tasks, such as caring for children and fetching water and firewood (Mwebi, 2007; Kirkbride & Grahn, 2008). Thus these differences could influence the results.

In addition, the presences of female herders in our study was probably due to the increasing number of men seeking employment away from home to supplement progressively more fragile incomes (Kirkbride & Grahn, 2008). In addition, the higher incidence of wild carnivore attack found in female herders were probably caused by their involvement more in domestic tasks than males (Mwebi, 2007; Kirkbride & Grahn, 2008).

Herding Equipment

In our study, we found a significant effect of equipment used by herders. Most attacks occurred when herders lacked equipment to protect their livestock from attacks by wild carnivores. In addition, herders equipped with bush knives and spears experienced fewest attacks, suggesting that they were more serious in caring for their livestock than those who lacked a weapon. These results hence supported partly our hypothesized that the use of equipment's such as spears and knives would reduce carnivore depredation. The Maasai herders were found to mostly use clubs and sticks, whereas the Sonjo tribe herders mostly used bush knives and spears. Despite this difference, we did not identify an effect of the tribe. Surprisingly, the use of herding equipment did not differ between gender or age class. Such knowledge will help improving wild carnivores' conservation in this area.

However, historically herders worldwide have been modifying and improving their herding techniques and equipment to overcome their enemies and thus enhance their coexistence (Mwebi, 2007). Previous studies have found that the use of only one defence method cannot completely solve herding problems because it requires a combination of more and improved techniques (Bangs & Shivik, 2001). Because using knives and spears as protection against wild carnivore had such a significant effect, herders are recommended to use a combination of more and improved methods

(Bangs & Shivik, 2001). However, domestic dogs could not reduce the attack rates in the LGCA. Thus, the use of dogs most likely requires well-trained dogs that are of special breeds used in livestock guarding (McGrew, 1983; Andelt, 1995; Sillero-Zubiri & Stwizer, 2004; Otstavel *et al*., 2009). Although dogs are used in our study area, they are not the only animals that can be used for livestock guarding. Donkeys were frequently used to defend livestock from predators in Namibia when Europeans owned farms a century ago. Here, the use of donkeys was very common to guard livestock (Rigg, 2001; Sillero-Zubiri & Stwizer, 2004). Furthermore, donkeys have been used to guard sheep in Switzerland since 1995 (Rigg, 2001). Donkeys can provide a high level of protection at a relatively low cost and level of maintenance (Rigg, 2001; Gese, 2003), and their use could be very beneficial in developing countries, where the cost of maintaining life-guarding dogs may be too high to be economically viable for most farmers (Sillero-Zubiri & Stwizer, 2004).

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Our results conclude that both tribes cared for their livestock while in the grazing field because all visited livestock herds were attended by at least one herder. Despite of that, still carnivores' attacks over livestock were found to occur. This was because herders lacked weapons to protect their livestock from the attacking carnivores. Also, it was because most of the herders more in the tribe owned large herd sizes which were unable to protect them. However, carrying defensive equipments (e.g., knife/ spear) by herders reduced carnivore attacks in the area. Therefore, we recommend that traditional livestock husbandry practises be maintained and improved as well as increasing the number adult male herders per herd.

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IMPACTS OF WILD ANIMALS TO LIVESTOCK: A CASE STUDY OF NGORONGORO DISTRICT

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ABSTRACT

The research was required to explore the impacts of wild animals to livestock in Ngorongoro District. The objectives were to; identify dangerous/problem wild animals to livestock in Ngorongoro District, assess the economic impacts caused by the wild animals and the way forward to mitigate the problem caused by the dangerous/problem wild animals. Primary data were collected by interviewing key informants (village leaders and affected livestock keepers) using questionnaire and through direct observations. Secondary data were obtained from literature and reports review. Quantitative information was analyzed using excel statistical software package. The results of this study are based on 1,202 cases of livestock death in 65 incidences reported in the district on livestock killed by wild animals from 2014 to 2017. Findings show that, the most important wild animal that caused much damage to livestock is wild dog (88.2%) followed by hyena (9.48%), leopard (1.33%), lion (0.91%) and the last is hippopotamus (0.08%). It was indicated that most attack incidences of livestock occur during the day (75.38%) than during the night (24.62%). The study also indicates that there are both positive and negative impacts of dangerous/problem wild animals in the district but the positive impacts overweigh the negative one. The research indicated that, the most affected villages are Ololosokwan (32.63%), Masusu (13.23%), Losoito (10.94%), Soitsambu (8.75%) and Kirtalo (6.26%) among the cases reported. The study also indicated that Human Wildlife Conflict incidences and Livestock damage decreased from 2014/2015 (78.62%) to 2016/2017 (22.38%). The study concluded that damages by wild animals to livestock have less negative impacts compared to benefits.

Key words: *Human-wildlife- conflict, livestock, Ngorongoro district, problem wild animals.*

INTRODUCTION

Ngorongoro District has encountered human wildlife conflict for many years (McCabe, *et al,* 1992). This conflict is caused by wild animals raiding livestock followed by livestock keeper revenging by killing, injuring or poisoning of wild animals. The people of Ngorongoro District recognize that wildlife has ecological, economic, social and cultural values. Residents in the protected area such as Loliondo Game Controlled Area (LGCA), Lake Natron Game Controlled Area (LNGA) and Ngorongoro Conservation Area (NCA) share responsibility for preventing and managing human-wildlife conflicts. In order to have effectiveness in prevention and management of human wildlife conflict, formulated strategies should be dependent on implementation of a variety of practical solutions through collaboration and discussion among stakeholders. Actions to address human-wildlife conflicts must be ecologically sound and should not negatively impact the survival and recovery of species at risk. Sound scientific and applied technical knowledge can enhance human-wildlife conflict prevention efforts and minimize risk to livestock health and safety (Osofsky, 2005).

Lions (*Panthera leo)* as well as other predators like leopards (*Panthera pardus)*, spotted hyena (*Crocuta crocuta)*, and African wild dogs (*Lycaon pictus)* are widely perceived as being persistent killers of livestock. Adding fuel to their negative perception, these predators are particularly likely to kill multiple animals on each attack, thus causing great economic loss (Thavarajah, 2008).

In Africa, pastoralists and their livestock have co-existed with wildlife for thousands of years, and it is likely that some of the tensions evident today existed in the past (Cumming, 1982; Bourn & Blench, 1999). Human-wildlife conflicts are prevalent in Africa where large numbers of carnivores such lions, leopards, wild dogs and hyena still roam freely in marginal rangelands and protected areas.

The increase in human population has resulted to encroachment into more marginal lands inhabited by wildlife, leading to fragmentation and conversion of land, for instance, to settlement, agriculture and other uses incompatible with wildlife. These, as Kangwana (1993), Conover (2002) and Okello *et al.,* (2003) contend do not only escalate conflicts between the people, wildlife, and the authorities responsible for the conservation of wildlife, but also pose a real challenge to sustainable wildlife conservation practice.

Lessons learnt from the African Wildlife Foundation (AWF) heartlands (Muruthi, 2005) elicit two basic approaches of managing human-wildlife conflicts: prevention and mitigation. Preventive measures are the ones that can prevent or minimize the risk of conflicts arising between people and animals and include the extreme one of completely removing either the people or the animals, physically separating the two by the use of barriers, and employing a variety of scaring and repelling tactics. Muruthi (2005) further observes that although prevention is clearly the best option, at times reactive approaches are required after human-wildlife conflicts have occurred.

Objective of the study

The main objective of the study was to assess the impact of wild animals to livestock in Ngorongoro District. The specific objectives were to; (i) Identify the problem wild animals to livestock in Ngorongoro District, (ii) Assess the benefits and costs of the problem wild animals to livestock and the community in the district, and (iii) Describe the best mitigation measures of HWC.

MATERIALS AND METHODS

This study was conducted from 2014 up to 2017. The results of this study are based on 1,202 cases of livestock death in 65 incidences reported in the District on livestock killed by wild animals from the year 2014 to 2017. The study focused on pastoralists living in the Ngorongoro District. The data was collected from causalities and village leaders that reported on the incidences of their livestock being raided or injured by problem animals such as Lions, Leopard, Hippopotamus, Wild dogs and Hyena. On receiving complaint from villages, Wildlife experts from the district attended the case and interrogate the respondents. The interviews were designed to collect data from respondents. The study also reviews secondary data from reports of previous researchers and wildlife sector as well as financial department in Ngorongoro District Council. The collected data was summarized, coded and analyzed used excel.

FINDINGS AND DISCUSSION

Identification of problem wild animals in the Ngorongoro District

Although other dangerous wild animals like elephant (*Loxodonta africana)* and buffalo (*Syncerus caffer*) were frequently reported to cause much damage to human in Ngorongoro District, the findings show that much damage to livestock is caused by wild dog (88.2%) followed by hyena (9.48%), leopard (1.33%), lion (0.91%) and the last is *Hippopotamus* (0.08%) See table 1.

Table 7: Problem wild animals to livestock in Ngorongoro District

Problem Wild Animal	Domestic Animal killed	Percentage
Hyena	114	9.48
Leopard	16	1.33
Lion	11	0.91
Wild dog	1060	88.2
Hippo	1	0.08
Grand Total	1202	100

Source: Surveyed data (2014-2017).

When we wanted to know on what time of the day problem wild animals attacked livestock, the study found that, most incidences of wild animals attacking livestock occur during the day (75.38%) than during the night (24.62%) As shown in Figure 1.

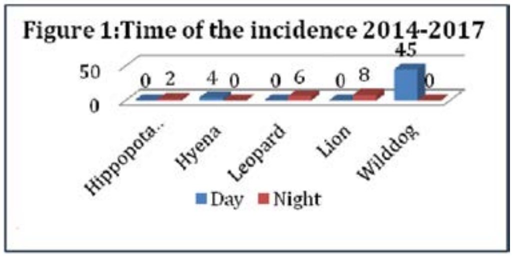

***Figure 1**: Time of incidence 2014-2017*

Source: Survey data (2014-2017).

This study went further to assess the spatial distribution of the incidences of problem wild animals in attacking livestock and found that Ololosokwan Village is more prone to wild animals' attacks and killings. Ololosokwan had 328 cases followed by Masusu sub-village with 113 cases and lastly Losoito Village with 110 cases (see Figure 2).

The study also showed that the total number of livestock killed in the study area was 1,015 which was 84% of the total livestock damaged by problem wild animals. The study further indicated that the total number of livestock injured in the study area was 187, which was 16% of the total livestock damaged.

When compared to the total number of incidences of livestock attack and number of livestock killed it was found that at Enguserosambu Village almost 39.4% of the attacked livestock survived compared

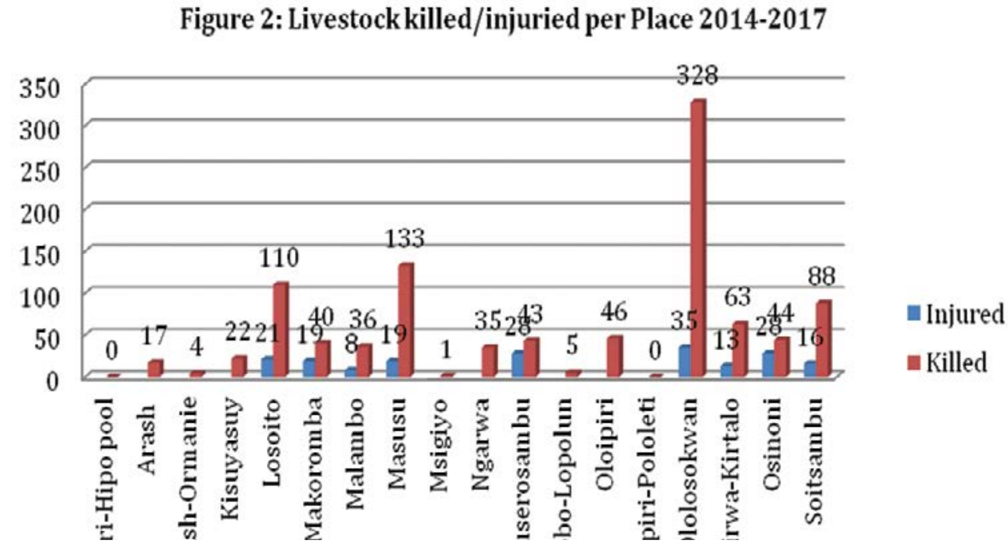

***Figure 6**: Livestock killed/injured per place (Source: Survey data 2014-2017).*

to Ololosokwan Village where only 9.6% survived. The reason for the differences was that in Enguserosambu Village the attack was by wild dogs alone while in Ololosokwan the attacks were from wild dogs, hyenas and lion. This suggests that wild dogs are more injurious to livestock than killing.

Assessment of the economic impact caused by the problem wild animals to livestock

The economic impact from wild animals attacks show that small stocks are more affected by wild carnivores than cattle as shown in table 2. However, in monetary terms the cost was higher compared to actual amount received from the government as consolation as shown in table 2 as well. The consolation price for a calf was the same as for the adult cow, which is not fair; at least the price for a cow should be twice that of a calf.

Table 2:Economical cost of problem wild animals to llivestock, 2014-2017

Type of Livestock	Number of livestock killed	Unit Value as per URT-Wildlife regulation 2011 (as damage consolation fund in TZSs.)	Total
Calves	53	50,000	2,650,000
Cow	12	50,000	600,000
Goat	593	25,000	14,825,000
Sheep	544	25,000	13,600,000
Total	1202		31,675,000

Source: Survey data (2014-2017) & WCR (2011).

The economic benefits of the Wild animals and wildlife related business to the Ngorongoro DC

The Ngorongoro District Council managed to collect TZS 823,226,514 in the year 2014/2015 from wildlife related revenue; this is 65.2 % of the total district revenue collected for the year. Also in the 2015/2016 the council collected TZS 1,027,145,894 which is 66.9 % of the total district revenue for the year. Likewise in the 2016/2017 thecouncil collected TZS 868,718,789 which is 55% of the total district revenue for the year. The total revenue collected from wildlife and related business is 2,719,091,197 which is greater by 62,07% of the total revenue collected in the district, whereby the total revenue collected from other sources to the District council is 1,661,475,855 which is 37.93% of the total revenue of the district. Hence, Wildlife and its related business are beneficial to the Ngorongoro District community (Table 3 & 4).

Table 3: Revenue from wild animals/ wildlife related business in Ngorongoro District Council in TZS.

NDC Revenue From Wild life / tourism business (TZS)	2014/2015	2015/2016	2016/2017	Grant Total
Photograghic and camping fees	77,232,387	250,134,788	154,800,706	482,167,881
25% C.G hunting fee	358,198,828	512,520,816	177,782,501	1,048,502,145
Local hunting fee	2,620,200	3,725,000	-	6,345,200
NCA Contribution	178,000,000	175,000,000	175,000,000	528,000,000
Ngarasero gate fee	59,257,249	85,765,290	126,110,227	271,132,766
Hunting block fees (OBC)	147,917,850	-	235,025,355	382,943,205
Total	823,226,514	1,027,145,894	868,718,789	2,719,091,197

Table 4: Revenue from other non-wildlife/tourism business in Ngorongoro DC in TZS.

NDC Revenue From other own sources (TZS)	2014/2015	2014/2015	2014/2015	Grant total
Total rev. from Non Wildlife/ tourism	439,011,080	510,522,077	711,942,698	1,661,475,855
Total rev. from Wildlife/ tourism and non wildlife/ tourism	1,262,237,594	1,537,676,971	1,580,661,487	4,380,576,052
% of rev. from Wild life / tourism business	65.21%	66.79%	54.95%	62.02%

Source: NDC –Financial Department.

Prevention and mitigation measures of human wildlife conflicts

Community awareness

According to FAO (2010), the first step is to raise people's awareness that they are in a wildlife protected area and of the potential consequences: living, working or travelling in areas with large carnivores calls for preparedness. Prevention consists of being alert, having sound knowledge of the environment and predator habits and using strategies to decrease the likelihood of being viewed as prey. The ultimate achievement will be sustainable wildlife populations and changed attitude on human perception toward wildlife conservation. The contribution of wildlife resources to development of local communities will change the popular notion that has made people label wildlife as a liability. Research and extension are meaningful tools to this end (Shemwetta & Kideghesho, 2000).

Compensation /Consolation

According to FAO (2010), Compensation schemes are intended to prevent people who bear the costs of living with wildlife from becoming enemies of conservation. The compensation mechanism must balance the costs of damage incurred by victims with benefits provided by income-generating activities or by state agencies or non-governmental organizations (NGOs). The mechanism might be (i) preventive in that it allows potential victims to benefit from wildlife activities through employment or income sharing, or (ii) compensatory in that it grants victims monetary or in-kind subsidies. Compensation is sometimes directed to households, but more often to communities. In uncontrolled remote areas where wildlife damage occurs, victims tend to seek compensation by themselves and to recover payment for losses by killing culprits and obtaining meat and cash from wildlife resources. Moreover, Campbell *et al.* (2000) note that the policy of non-compensation for individual losses and damage to property, such as predation of livestock goes against the demands of conflict prevention.

There are some problem wild animals that are not included in the list of dangerous animals according to the Tanzania Wildlife Conservation Act no. 5 of 2009 and the Wildlife Conservation (dangerous animals' damage consolation) Regulation 2011, URT, 2011). This study found that wild dogs caused much damage to livestock compared to other problem wild animals (figure 4) but wild dog is not recognized as dangerous wild animals. For this case when wild dog cause damage to livestock, no damage consolation fund will be provided to livestock owners. This deficiency calls for review of the Wildlife Conservation (dangerous animals' damage consolation) Regulation 2011 to help in changing the attitude of pastoralists towards loving wildlife.

Livestock management

Predation on livestock is to some extent preventable. Preventive measures include protection of livestock and measures to prevent predators from forming the habits of killing livestock. Effective livestock husbandry can reduce predation and mitigate the impact of predators on human livelihoods. Livestock have always been guarded to protect them against predators. The accustomed ways of herding livestock where young boys used to protect herds at night and during the day time, rather than elders increases chances of livestock of being raided by problem wild animals.

Wild Animal Deterrent Method

Many devices can be used to deter wild animals such as lion attacks: the two main types are those that frighten and those that cause aversion. Fires can be kept burning at night in areas where animals make regular raids. The most common deterrents are dogs and human guards with weapons. Solar LED predator deterrent lights, which are installed around pastoralists' bomas, prevent predators to enter into the bomas during the night and raid the livestock. Currently, in Ngorongoro District Solar LED predator deterrent lights have been installed in 67 bomas by Tanzania Lion Illumination Project whereby it has shown positive impact.

Translocation of problem animals

According to FAO (2010) Translocation of large carnivores is a sophisticated management practice with a relatively low success. Before large carnivore such as lion are moved, consideration must be given to the destination at which they are to be released. There would be repercussions if they are released in areas already inhabited by lion prides or utilized by livestock herds. The African wild dog is one of the world's most endangered large carnivores and presents a particular challenge for conservation because they live in low population densities but range very widely (Masenga, 2011). Translocation of wild dogs from Ngorongoro District reduced human-wildlife conflict. Due to continued incidences problem wild animals attack to livestock, TANAPA, Ngorongoro District Council (NDC), WD, NCAA and TAWIRI in 2012 onwards executed wild dog translocation from Ngorongoro District to Serengeti that aimed to reduce the incidences in the district among others. When this study compared the number of incidences and livestock damage for four years from 2014 to 2017 it was revealed that there was a downward trend on number of incidences of livestock damage from 2014-2015 to 2016-2017. (Figure 3)

Since April 2015, two packs have been released into the Nyasirori area, southeast of Singita Sabora Tented Camp, and a year later, the packs fussed into one and seven new pups were whelped (Figure 4).

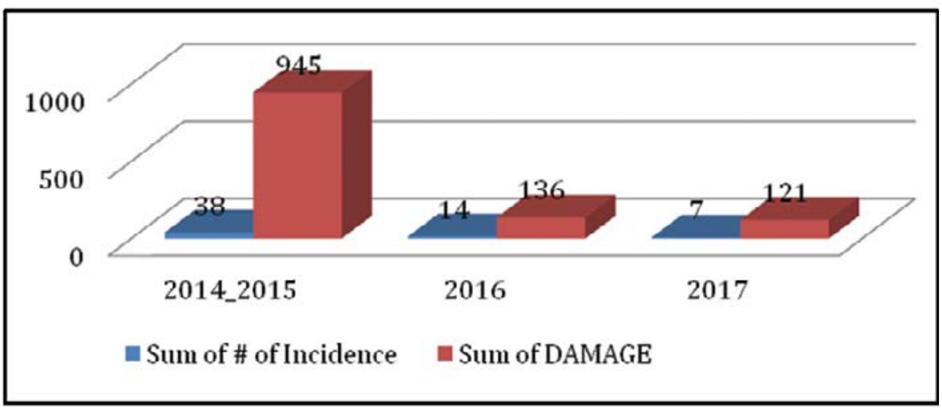

Figure 3: *Relationship between HWC incidence and damage from 2014-2017*

CONCLUSION

The problem wild animals to livestock are lion, wild dogs, leopard, Hippopotamus and hyena. However, wild dog caused most of the damage followed by hyena, leopard, lion and the last is *Hippopotamus*. Most incidences of wild animals attacking livestock occur during the day than during the night.

The main tourism attraction in the district is wild animals. For this case, wild animals provide substantial economy to the district; hence the damages caused by wild animals to livestock should be contained while allowing co-existence of both wildlife and livestock in the district.

The usual habit of herding livestock using young boys to protect livestock during the day and at night hours, rather than elders increases chances of livestock being raided by problem wild animals. In understanding that livestock is the main source of livelihoods in the district,it is important to provide high security to prevent depredation. Also the use of solar lights as deterrent has shown significant results in the pastoralists'bomas.

RECOMMENDATIONS

On the basis of the research findings and foregoing analysis, I recommend the following;The government is urged to recognize wild dogs as among the dangerous wild animals such as lions, spotted hyenas, African elephants, Hippopotamus, Nile Crocodiles, black rhinos (*Diceros bicornis*) and Buffaloes. Recognition of wild dogs as dangerous wild animals will allow people whose livestock are damaged to receive consolation fund, this will reduce the conflict between wildlife and livestock keepers.

The government is also urged to make amendment to Wildlife Conservation Act No.5 of 2009 and the Wildlife Conservation regulation (Dangerous Animal Damage Consolation Regulations) of the 2011, by including Wild dog in the list of dangerous wild animals.

In order to enhance community conservation and sustainable conservation of Natural resources in Ngorongoro District, and elsewhere the Ministry of Natural Resources and Tourism or TAWA should pay consolation fund expediently for the people/ livestock killed by dangerous wild animals. Also the amount given as consolation to victims is too small compared to actual loss, therefore it needs to be looked at.

Land-use planning should be done in order to ensure that human activities are not conducted in wildlife protected areas to prevent human- wildlife-conflict.

Mitigation by ensuring that people perceive wildlife more positively can be applied in cases where human-wildlife conflict is common. Interest in the benefits generated by wildlife will increase tolerance to the community in protected areas.

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ASSESSMENT OF ANTHROPOGENIC ACTIVITIES, TREE SPECIES COMPOSITION AND DIVERSITY AT NKOANENKOLE CATCHMENT FOREST RESERVE IN ARUMERU DISTRICT

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ABSTRACT

The study was conducted at Nkoanenkole Catchment Forest Reserve to examine activities affecting tree species composition, diversity and dominance. A total of 34 concentric plots with a radius of 15m were established systematically at an interval of 250m to each other. In each plot the following information were measure and recorded: diameter at breast height (1.3m), species abundance, scientific names, coordinates and all activities occurring to the forest. Shannon Wiener Index and Simpson Index indices were used to compute species diversity and dominance indices respectively in Microsoft excel. Activities found to occur in the forest were summarized in terms of frequency and percentages in Microsoft excel. A total of 57 tree species belonging to 25 families were identified, measured and recorded. The study further, recorded a diversity and dominance index of 2.17 and 0.05 respectively, an implication of relatively high tree species diversity in such a small forested area. This implied that there had been moderate disturbance at some stage that could have allowed several other trees to regenerate. Also, this is an indicator that conservation management has been successful and hence contributes high tree species diversity in the forest. Firewood collection, fodder collection illegal harvesting timber and poles were identified as most frequent activities done in the forest, and thus affect tree species diversity. This study recommends forest conservation education should be given continuously to the community, and non-woody income generating projects should be introduced in order to reduce pressure to the forest resources from adjacent communities.

***Key words**: Tree species diversity, dominance, richness*

INTRODUCTION

The natural vegetation layer constitutes a permanent component of vegetation that gives the main physiognomy to the land cover and permits the classification of vegetation types (Kperkouma *et al.,* 2006). Natural vegetation includes shrub lands, woodlands and forests that are conducive to other living organisms such as honey bees (Smith, 1991). The biological diversity assessment is one of the main objectives that encourage the studies on natural resources and ecosystems (Fichtl, 1995). Most natural ecosystems are fragile due to the disturbances caused by human activities involving the removal of plants for poles, timber, firewood and charcoal (Kperkouma *et al.,* 2006). Studies on plant diversity has revealed that the important plant habitats are subject to increasing level of encroachment as pressure for land and plant resources that force people encroach into natural environment and protected areas (Lovett *et al.,* 2006). Human activities, both local and global are modifying botanical diversity at an alarming state (Maunder and Clubbe, 2002) consequently, species loss and extinction. The extinction of tropical plants due to cultivation, overexploitation have been learned to adversely affect the natural ecosystems diversity (Llamas, 2003). Also, the introduction of new vegetation (exotic trees) replacing the natural tropical vegetation has been revealed to further the depletion of natural ecosystem hence reducing the plant species diversity and composition (Llamas, 2003).

The challenges facing the forest sector are well known some, of which are shifting cultivation, settlement expansion, overgrazing, and encroachment in forest reserves, illegal logging, and illegal mining and forest fires (URT, 2004). Those activities resulted into the loss of forest resources, desertification and inadequate information on the quantity (Kilahama, 2008). Against this background the existing quality and quantity of tree species needs to be understood through systematic methods (Katende *et al.,* 1999). The type of forest tree species and other related data are relied on organized data collection (Munishi *et al*., 2009). The sustainable uses and management of forests are possible when the present plant varieties are determined (Kundzewicz, 1997; Vorosmarty et al., 2000). Nkoanenkole Catchment Forest Reserve (NCFR) is one of the famous localities in Tanzania for its tree species composition with such a small size of land, and was declared as Joint Forest Management (JFM) by the government of Tanzania in 2004. The catchment forest reserve comprises of enormous woody tree species diversity, which calls for systematic investigation to capture important information for further sustainable environmental and forest management strategy. This study therefore, aimed to examine human activities affecting tree species composition and diversity at Nkoanenkole Catchment Forest Reserve, in Meru district.

MATERIALS AND METHODS

The study area

The NCFR is located between Latitude of 30 19^{I} and 3° 20^{I} South of Equator and between Longitude of 36° 50^{I} and 36^{0} 52^{I} East of Greenwich Meridian. The NCFR is about 3.5 km North of USA River Township and 28 km North East of Arusha City. The altitude ranges from 1300 -1800 m above sea level. The selection of this as a study area was due to its potential in terms of its unique tree species composition. The NCFR covers 100 hectares, equivalent to 250 acres. The forest reserve experiences the oceanic rainfall with continental temperatures. Rainfall on the southern slopes of Mount Meru is up to 2000 mm per year, while the northern slopes which are meant to be Leeward side receive rainfall between 500-600 mm per year. The mean annual temperature is between 17 and 20 degrees centigrade at lower altitudes. It is an underground water sub-Afromontane forest dominated by *Celtis africana, Vepris simplicifolia, Tabernaemonatana ventricosa, Rauvolfia caffra, Rothmania urceliformis, Trilepesium madagascariensis, Diospyros usambarensis* and *Albizia schimperiana* just to mention a few. The soils are Andosols on young volcanic stone (basalt lava) rich in nutrients and alkaline (soda). At higher altitudes, the soil is leached forming acidic lithosols (Kashenge, 1986). The NCFR is a source of water, hence has water catchment value. The water is piped and distributed to the USA River Township for domestic use and irrigation farming.

Sampling procedure and sample size

Systematic and random sampling was applied starting with first plot established randomly 50m from forest boundary to avoid edge effect, thereafter; plots were laid systematically at an interval of 250m between plots. A total of 34 circular plots with 15m radius were established for data collection. A Sample size of 34 plots in this study was determined using the following formula:-

$$n = \frac{(TA * Si)}{(Ps * 100)}$$

Where: ***n*** = number of sample plots; ***TA*** = total area of the forest; *PS* = Plot Size (size of sample plot (ha)), ***Si*** = sampling intensity which was 2.4% (0.024). Synnott, (1979) recommended the sampling intensity to be within a range of 5% (0.05) to 7% (0.07) for tropical natural forest inventories. However, according to Malimbwi and Mugasha, (2002) and Malimbwi et al., (2005) it was highlighted that financial and time constraints and purpose of the forest inventory may dictate the sampling intensity to be as low as 1% (0.01). Given sampling intensity of 0.024, plot size of 0.071ha and a forest of 100 ha. The number of plots shall be 34 plots.

Data collection

In each plot tree species were measured and recorded for their abundance, frequency and diameter at breast height (dbh) at 1.3m. GPS coordinates were also taken at the center of each plot. Moreover, any sign of human activities encountered during the taking of forest inventory were recorded.

Data analysis

Tree species diversity was computed by using Shannon Wiener Index formula, H'= -∑ (Pi*lnPi). Where; H'= Shannon Wiener Diversity Index, ∑ = summation symbol from 1^{st} to i^{th} species, Pi = proportional of importance value as a species as a proportion of all species, ln = natural logarithm. The Shannon Index of Diversity Index is the best index due to the reason that it combines both species richness and evenness and less affected by sample size compared to other indices (Giliba *et al.,* 2011; Kent and Coker, 1994). Tree species dominance was computed by using the Simpson Index formula, C = $\sum (n/N)^2$. Where n= total count of individual tree species, N= total count of individual of all tree species identified in the sample. Moreover, all tree species found was counted and grouped accordingly to their families and percentage were calculated to determine the most dominant family according to the total number of tree species belonging to a particular family; P =. (∑ n/∑N) x 100% (Kent and Coker, 1992); where:- P = family percentage, ∑ = summation, n = total number of tree species per family, N= the total number of all tree species identified in the sample plots for all families.

RESULTS AND DISCUSSION

Tree species composition

A total of 57 tree species were identified belonging to 25 families and 48 general from 34 sample plots surveyed (Table 1 and Appendix 1 and 2). This implies that apart from being a small area covered by forest, there were relatively many varieties of tree species found in the study area. This could have been stimulated by moderate disturbance in the previous years, a process that could have allowed other tree species to regenerate which do not require dense forest cover in order to grow. However, it is revealed that at some stage the disturbance was reduced to the minimum an indication of tree species conservation improvement by the government in collaboration with the community. Sapkota et al. (2010) reported that very high diversity of plants has influence on the diversity index and is associated with moderate disturbance a process which opens a room for regenerating trees. Moderate disturbance is associated with proper management of forest resources utilization of which at some stage the disturbance must be stopped or kept to the minimum to maintain the species diversity.

Table 1: Tree parameters in the study area

Parameters	Value
Species richness	57
Species abundance	437
Species diversity	2.17
species dominance	0.05
Plant families	25
Genera	48

Diversity Index

The study recorded a Shannon-Wiener Index of diversity (H′) of 2.17 in the study area (Table 1 and Appendix 1). An ecosystem with H′ value greater than 2 has been regarded as medium to high diverse in terms of species (Barbour *et al*., 1999). The larger the value of H′ the greater the species diversity and vice versa is true. In this case, the study area consists of relatively high tree species diversity in such a small area. Tree species found to have higher diversity index were *Celtis africana* (0.057), *Diospyros usambarensis* (0.045), *Euclea divinorum* (0.025), *Casearia battiscombei* (0.025), *Croton sylivaticus* (0.019), *Olea capensis* (0.016), *Tabernaemontana ventricosa* (0.014) and *Blighia unijugata* (0.014) (Figure 1 and Appendix 1). Diversity index plays a role in showing the richness of tree species or plants in general in a particular geographical location. It also, helps in creating awareness on the different species available and thus contributing to management and or control of the utilization of the tree species resource. Very high diversity index is associated with moderate disturbance that paves a way for other regenerating trees (Sapkota et al., 2010). While for most undisturbed ecosystems population diversity is meant to be less due to prohibited regeneration and thus opportunistic plants including trees take over and thus dominating a certain locality while diversity becomes low (Giliba, *et al,* 2011).

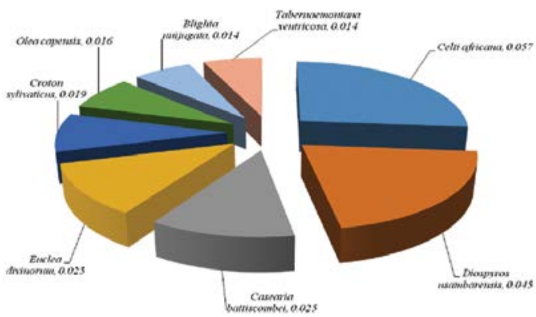

Figure 1: *Tree species with higher diversity value in the study area*

Tree species dominance

The study recorded an index of dominance (C) of 0.05 in the study area. The lower the index value, the lower the dominance of a single or few species (Edward 1996). Misra (1989) reported the greater the value of index of dominance the lower the species diversity and vice versa in the scale of 0 to 1. The index of dominance value in this study is relative smaller and hence the high the species diversity as it has been reported in section 3.2. The tree species with the high value of dominance index were the ones with the high diversity index (Figure 2) and those with low dominance index revealed lowest diversity index (Appendix 1). As a matter of fact of species recorded to have many individuals are the ones contributed to the high species diversity in the study area. This is in line with (Giliba *et al*., 2011) who reported that species with high abundance usually have higher diversity index and thus the lower the dominance index

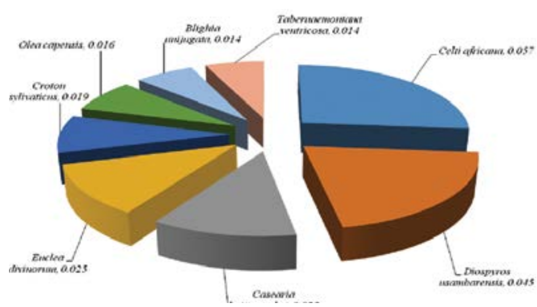

Figure 2: *Tree species with higher dominance value in the study area*

Contribution of tree species to plant family

The study recorded a total of 25 families comprising of 57 identified tree species in the 34 sample plots. Seven dominant families had tree species between 5-12% each, (Figure 3 and Appendix 2). According to this study those families with 5-12% were considered to be the dominant ad contributed many tree species. This meant that different families did not reveal to have many tree species. There may be many families but few species, while on the other hand there may be few families but many species. If our interest is to maintain more tree species families then strategies may be set to introduce more families of interest under certain control according to the community and conservation interest.

It if there are many families, and most of them include invasive exotic tree species, management efforts can be initiated to remove the excessive stubborn families in the natural environment or stop disturbance to inhibit the disturbance demanding trees. Sapkota *et al.* (2010), highlighted that most tree species including exotics prefer regenerating vigorously after a certain level of disturbance, but excessive disturbance will lead to depletion of forests. In case the family accommodates only one species which seem to cover large area, it may encourage introducing a moderate disturbance to allow other tree species. This may be through allowing harvesting and then planting other selected tree species to maintain diversity in the ecosystem.

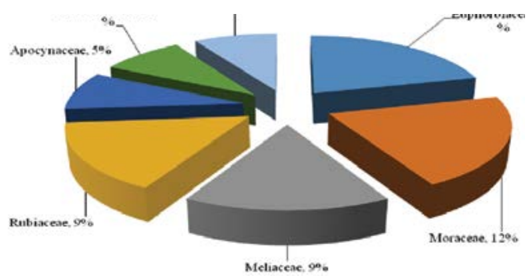

Figure 3: *Family Percentage in terms of number of tree species at NCFR*

Anthropogenic activities

A total of nine (9) activities were observed in the forest. The activity with high frequency of occurrence is firewood collection appeared in 27 plots out of 34 plots, followed by fodder collection occurred in

18 plots, footpath occurred in 9 plots, old and new timber cutting occurred in 8 plots and cutting poles occurred in 7 plots (Table 2). Other activities recorded to have low frequency of occurrence include clearing for beekeeping sites, traditional honey hunting, and excavation for road construction (Table 3). The general implication is demand for firewood, fodder and timber for domestic purposes, livestock and sale was high nearby communities from Killinga, Nkoanenkole and Ngongongare villages causing threat to tree species diversity. The distance between the homestead and forest reserve ranged from 1 to 3 km with a mean of 2 km. According to Giliba *et al*., (2011) distance to forest have big implications to the access of forest resources. The distance between the homestead and Njana (2008) reported that an increase in distance between homestead and the forest constrains the woodland's contribution to the livelihood of local communities. Similarly, Grundy et al. (1983) recorded the spatial effects of forest resource use and showed that an increase in distance from homestead to the forest raised costs of resource collection and vice versa.

Table 2: Anthropogenic activities in the study area

Activity	Frequency	Percentage
Firewood collection	27	36.49
Fodder collection	18	24.32
Foot path	9	12.16
Timber	8	10.81
Cutting Poles	7	9.46
Clearing for beekeeping site	2	2.70
Excavation for road construction	2	2.70
Traditional honey hunting	1	1.35
Total	**74**	**100**

CONCLUSION AND RECOMMENDATIONS

Nkoanenkole Catchment Forest Reserve consists of relatively high tree species diversity in such a small size of forest surrounded by settlements and plantation in the North. The diversity index of 2.17 was an indication of relatively high tree species diversity that could have been facilitated by a certain level of disturbance at same stage previously. Some tree species had higher dominance index while the others had low diversity index, but both of them contributed to the diversity of the area as the diversity accounts for the existence of the tree species, while dominance depends on the frequency of any particular tree species identified in a given geographical area. It also, revealed that there had been adequate efforts on tree species conservation after the occurred moderate disturbance. Proper conservation of forest for the future many years will lead to decrease of tree species diversity resulted from competition among trees, and thus requiring the forest conservation authority to allow minimum disturbance under set bylaws and laws to allow tree species not requiring too dense forest to come up in to maintain tree species diversity. Minimum disturbance may include: collection of dead woods for firewood, collection of grass for zero grazed livestock beekeeping and ecotourism. Illegal activities including tree cutting for firewood, poles and timber; traditional honey hunting using fire have negative influence to the tree species composition and diversity. In order to sustain the Nkoanenkole Catchment Forest Reserve, this study recommends the following:

Indigenous tree species should be planted in the existing gaps or replaced in areas where exotic plants have covered. Exotic plants including the invasive wood climbers: *Caesalpinia decapetala* and *Lantana camara* should be eliminated to allow the growth of native tree species.

Forest conservation education should be shared regularly among stakeholders including the foresters, beekeeping extension officers and local community through seminars, courses, meetings, workshops and leaflets distributed to the community.

Non-woody income generating projects such as mushroom production and beekeeping should be established by the district council in collaboration with the community sustainable development and environment.

Woodlots should be encouraged by the forest extension officers as source of fire wood, charcoal, poles and timber for the households to reduce pressure to the natural forest.

Further study should be conducted by the environmentalists including foresters, botanists and beekeepers from research and learning institutions to assess all plant species composition and diversity and their link to honey bees.

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APPENDICES

Appendix 1: Tree species list, species frequency and diversity index.

SN	Scientific name	Abundance	Dominance Index	Diversity Index
1	*Celti africana*	50	0.0131	0.0568
2	*Diospyros usambarensis*	43	0.0097	0.0449
3	*Casearia battiscombei*	30	0.0047	0.0252
4	*Euclea divinorum*	30	0.0047	0.0252
5	*Croton sylivaticus*	25	0.0033	0.0187
6	*Olea capensis*	23	0.0028	0.0163
7	*Blighia unijugata*	21	0.0023	0.0140
8	*Tabernaemontana ventricosa*	21	0.0023	0.0140
9	*Oxyanthus speciosus*	15	0.0012	0.0079
10	*Bersama abyssinica*	11	0.0006	0.0047
11	*Croton macrostachyus*	11	0.0006	0.0047
12	*Ehretia cymosa*	11	0.0006	0.0047
13	*Rothmania urceliformis*	11	0.0006	0.0047
14	*Vepris simplicifolia*	10	0.0005	0.0040
15	*Allophyllus africanus*	9	0.0004	0.0033
16	*Psychotria riparia*	9	0.0004	0.0033
17	*Ficus exasperata*	7	0.0003	0.0021
18	*Trichilia emetica*	7	0.0003	0.0021
19	*Ekebergia capensis*	6	0.0002	0.0016
20	*Ficus thonningii*	5	0.0001	0.0012
21	*Turraea robusta*	5	0.0001	0.0012
22	Alangium chinense	4	0.0001	0.0008
23	*Albizia gummifera*	4	0.0001	0.0008
24	*Combretum molle*	4	0.0001	0.0008
25	Fagaropsis angolensis	4	0.0001	0.0008
26	Ficus ingens	4	0.0001	0.0008
27	Oncoba spinosa	4	0.0001	0.0008
28	Peddiea fischeri	4	0.0001	0.0008

29	Ficus ovata	3	0.0000	0.0005
30	Ficus sur	3	0.0000	0.0005
31	Maytenus heterophylla	3	0.0000	0.0005
32	Nuxia congesta	3	0.0000	0.0005
33	Rauvolfia caffra	3	0.0000	0.0005
34	Syzygium guineense	3	0.0000	0.0005
35	Turraea holstii	3	0.0000	0.0005
36	Bridelia micrantha	2	0.0000	0.0002
37	Chaetacme arista	2	0.0000	0.0002
38	Dovyalis abyssinica	2	0.0000	0.0002
39	Erythrococca fischeri	2	0.0000	0.0002
40	Synadenium cuplare	2	0.0000	0.0002
41	Trilepesium madagascariensis	2	0.0000	0.0002
42	Antidesma venosum	1	0.0000	0.0001
43	Cordia abyssinica	1	0.0000	0.0001
44	Cussonia holstii	1	0.0000	0.0001
45	Ficus sycomorus	1	0.0000	0.0001
46	Kigelia africana	1	0.0000	0.0001
47	Leopidotrichilia volkensii	1	0.0000	0.0001
48	Maesa lanceolata	1	0.0000	0.0001
49	Maytenus acuminata	1	0.0000	0.0001
50	Mimusops kummel	1	0.0000	0.0001
51	Phyllanthus delpyanus	1	0.0000	0.0001
52	Psidium guajava	1	0.0000	0.0001
53	Tabernaemontana stapfiana	1	0.0000	0.0001
54	Trema orientalis	1	0.0000	0.0001
55	Tricalysia sp.	1	0.0000	0.0001
56	Vangueria madagascariensis	1	0.0000	0.0001
57	Vernonia myrantha	1	0.0000	0.0001
	Total	**437**	**0.0500**	**2.7175**

Appendix 2: Total number of tree species against genera and family

S/N	Family	Scientific name	Genera	Species	Family (%)
1	Alangiaceae	*Alangium chinense*	1	1	2
2	Apocynaceae	*Rauvolfia caffra*			
		Tabernaemontana stapfiana	2	3	5
		Tabernaemontana ventricosa			
3	Araliaceae	*Cussonia holstii*	1	1	2
4	Asteraceae	*Vernonia myrantha*	1		2
5	Bignoniaceae	*Kigelia Africana*	1		2
6	Boraginaceae	*Cordia abyssinica*	2		4
		Ehretia cymosa			
7	Celasteraceae	*Maytenus acuminate*	1	2	4
		Maytenus heterophylla			
8	Combretaceae	*Combretum molle*	1	1	2
9	Ebenaceae	*Diospyros usambarensis*	2	2	4
		Euclea divinorum			
10	Euphorbiaceae	*Antidesma venosum*			
		Bridelia micrantha			
		Croton macrostachyus			
		Croton sylivaticus	6	7	12
		Erythrococca fischeri			
		Phyllanthus delpyanus			
		Synadenium cuplare			
11	Flacourtiaceae	*Casearia battiscombei*			
		Dovyalis abyssinica	3	3	5
		Oncoba spinosa			
12	Loganiaceae	*Nuxia congesta*	1	1	2
13	Meliaceae	*Ekebergia capensis*			
		Leopidotrichilia volkensii			9
		Trichilia emetica	3	5	
		Turraea holstii			
		Turraea robusta			
14	Melianthaceae	*Bersama abyssinica*	1	1	2
15	Mimosaceae	*Albizia gummifera*	1	1	2

16	Moraceae	*Ficus exasperate* *Ficus ingens* *Ficus ovate* *Ficus sur* *Ficus sycomorus* *Ficus thonningii* *Trilepesium madagascariensis*	2	7	12
17	Myrsinaceae	*Maesa lanceolata*	1	1	2
18	Myrtaceae	*Psidium guajava* *Syzygium guineense*	2	2	4
19	Oleaceae	*Olea capensis*			2
20	Rubiaceae	*Oxyanthus speciosus* *Psychotria riparia* *Rothmania urceliformis* *Tricalysia* sp *Vangueria madagascariensis*	5	5	9
21	Rutaceae	*Fagaropsis angolensis* *Vepris simplicifolia*	2	2	4
22	Sapindaceae	*Allophyllus africanus* *Blighia unijugata*	2	2	4
23	Sapotaceae	*Mimusops kummel*	1		2
24	Thymeleaceae	*Peddiea fischeri*	1		2
25	Ulmaceae	*Celti africana* *Chaetacme arista* *Trema orientalis*	3	3	5
	Total		**48**	**57**	**100%**

A SURVEY OF MEDICINAL PLANTS USED BY INDIGENOUS PEOPLE IN NORTHERN TANZANIA

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ABSTRACT

Tanzania has more than 120 ethnic groups with diverse knowledge on the use of wild plants for medicines. Very little of this valuable information is recorded in most of the ethnic groups on knowledge, attitude and practices related to use of medicinal plants in many parts of Tanzania. This study documented indigenous knowledge on use of medicinal plants in Northern Tanzania. Household questionnaires, focus group discussion, key informant interviews and observational survey were used during data collection for five ethnic groups in Northern Tanzania namely Maasai and Sonjo in Ngorongoro District, Hadzabe, Iraqw and Tatoga in Mbulu District. Data were analyzed using Descriptive statistics. Results indicate that communities in northern Tanzania have significant knowledge on the use of medicinal plants, and this has immense contribution to the livelihood and health security. A total of 131 species are used to treat more than 15 diseases and health conditions. The Fabaceae family was leading with 19 species, followed by Euphorbiaceae (9 species). Twenty eight species in 19 families were mentioned by at least 1% of the people. The leading among the 28 species were Harrisonia abyssinica (6.6%) and Xanthoxylum chalybeum (5.3%) followed by Turrea nilotica (4.1%) and Warburgia salutaris (3.6%) which were mentioned by the Maasai and Sonjo in the Ngorongoro District. Of the 25 highly mentioned species, two represent the most widely known and used because they were mentioned by four out of five ethnic groups; these include Acacia nilotica (3.4%), and Cassia abbreviata (2.3%). This study has shown that ethno botanical knowledge offers a basis for prioritizing further phytochemical and pharmacological studies of medicinal plants that are used to treat chronic diseases. However, studies involving chemical and biological investigation to authenticate such local people's experiences could help in suggesting effective usage of medicinal plants for sustainable use of the species.

***Key words**: Traditional medicine, Northern Tanzania, ethno-botany.*

INTRODUCTION

Plants are important as habitats for living organisms (Westrich 1996) and help in water cycles (Gunatilake 1998, Asada 1999). In the human context, useful plants have been handled, especially for medicinal purposes (Begossi et al. 2002, Upadhyay et al. 2007), among other uses (Szego and Kemp 1973, Gunatilake et al. 1993, Cunningham 1996, Van Wyk and Gericke 2000) by human societies since ancient time. Medicinal plants are essential components of primary health care, especially for the rural communities, who by geographical and economic reasons cannot access the modern western medical services (Msuya and Kideghesho 2009). The world population relying on traditional medicines for their primary health care is estimated to be four billion people, 80% of them coming from developing countries (Augustino and Gillah 2005, Schippmann et al. 2006). Neuwinger (2000), estimated that 5,400 wild plant species are harvested and used in traditional medicine in Africa, where the high reliance on traditional medicines is mainly caused by a low ratio of the university trained doctors to rural populations. For example, the ratios of traditional healers and that of medical doctors to patients in Uganda were 1:708 and 1:25,000 (Worldbank 1993) and Malawi - 1:138 and 1:50,000 (Msonthi and Seyani 1986) respectively. As for other African countries, Tanzania faces inadequate and poor accessibility to western medical services as well as the low purchasing power among the rural people, which has been manifested by a high imbalance ratio between traditional healers and modern medical doctors (Green 2000) and increased human population is exacerbating this imbalance (Ishengoma and Gillah 2002, Augustino and Gillah 2005).

Tanzania has more than 12,000 plant species (Mahunnah and Mshigeni 1996) out of which 25 % are known to be of medicinal plant species (ITM 2012), while more than 1,600 are endemic (Bukombe *et al.,*2014, unpublished data). Tanzania is rich in cultural diversity, with over 120 indigenous ethnic groups across the country. Ethnicity in Tanzania is also a product of the geographic area, as each tribe is concentrated on various parts of the country, and are rich in traditional knowledge on the use of wild plants for medicines. It has been shown that, traditional medicine plays a very important role in in the country owing to the high cost of western medicine (Otieno 2000), whereby about 60 % of the population depends on traditional medicine for treating various diseases including the HIV/AIDS pandemic (Kisangau et al. 2011). The role of some medicinal plants in Tanzania has been documented in some areas and tribes for example, in Tabora Region (Karachi et al. 1991), Uluguru Mountain (Mahonge et al. 2006) and for Mahale (Huffman *et al.* 1997).

The selected ethnic groups in this study including Maasai, Sonjo or the Batemi in Ngorongoro district and Iraqw, Hadzabe and Tatoga in Mbulu and Hanang are among the well-known groups occupying in the three districts with rich traditional knowledge on the use and management of wild plants in northern Tanzania. The Maasai have their knowledge of traditional plant uses which is more than 2,000 years' experience (Homewood et al. 1987, Searle 1999). The long term traditional use of plants by the Sonjo who are also known as Batemi have been described (Johns et al. 1994). Iraqw is well known for the great variation in wild plants due to the geographical diversity and climatic circumstances, and the use of plants can be traced back to the Sumerian period (3000-1970 B.C.) and then to the Babylonian and Assyrian periods (1970-589B.C.) (Al–Douri 2014). The Hadzabe are hunter-gatherers, their traditional use of plants is estimated to be 130 -200,000 years old (Mehlman 1987, Marlowe 2002). The traditional use of plants for medicine were previously documented for the Maasai (Johns *et al.,* 1994, Searle 1999), the Sonjo (Johns *et al.*, 1994), the Iraqw (Albayaty 2011, Al–Douri 2014) while the Hadzabe who are well known as hunter gatherers (Crittenden et al., 2017), their plant use for medicine is partially documented.

The importance of medicinal plants in traditional healthcare practices is critical for providing clues to new areas of research and biodiversity conservation. Lack of documentation limits development in medicinal research as well as planning strategies for conservation for the sustainability of the highly utilized wild species.

This study aimed to document the indigenous knowledge of the four ethnic groups related to uses of wild plant species for both food and medicines, determine the social-economic potential of the plant species, and also to assess the status of the wild plants used for medicine with emphasis on: i. Medicinal plant species composition and their parts used by five selected ethnic groups with emphasis on the highly utilized species in the three Districts; ii. Common diseases/ill health conditions treated by traditional medicine in the area.

METHODOLOGY

Description of the study area

The study area is located in three districts (Mbulu, Hanang and Ngorongo) of the Northern corner of Tanzania. Four ethnic groups were studied including the Maasai and Sonjo in Ngorongoro District; Iraqw, Hadzabe and Tatoga in both Mbulu and Hanang Districts (Figure 1). The occupation of the Maasai was purely pastoralist and that of Hadzape were gatherers and hunters. The rest ethnic groups were involved both in pastoralism and agriculture. There were few health facilities and in some villages of the study area, the health facilities were not accessible because were located more than 30 km away. The four ethnic groups were chosen because they had rich traditional knowledge on the use of wild plants. However, despite the rich traditional knowledge on the use of wild plants for both food and medicines in the four targeted ethnic groups, little has been documented and hence the need to document the indigenous knowledge of medicinal and food plants for further studies.

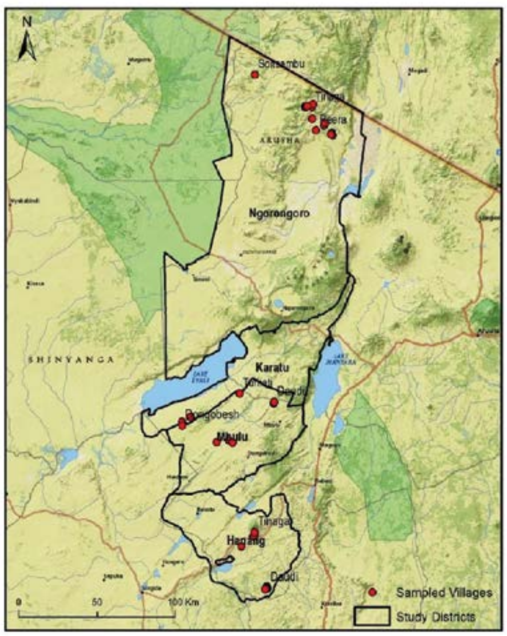

Figure 1: *The study area*

Data Collection Methods

Data were collected from three Districts represented by the five ethnic groups using four techniques including group discussions (FGDs), household questionnaire survey, Key informant interviews and Field observations between July 2016 and December 2017. Besides the house survey respondents with the knowledge of use or experience including those with specified ethno botanical knowledge were used as key informants for in-depth interview and for FGDs. This led to purposive selection of 27 respondents as key informants and the rest for five FGDs that averaged 10-12 respondents per group. The collected information on medicinal and food plants from in-depth interview and FGDs supplemented the information from household survey. An assessment of the commonly used medicinal plants were conducted by consulting the local communities using participatory rural appraisal (PRA) approach, whereby household, key informants and FGDs questionnaires were administered face to face at each selected village to allow sharing indigenous knowledge and experience.

The plant species mentioned during interviews, questionnaires and FGDs were authenticated in the field through observation by walking randomly within village areas with the key informants to appraise the names, existence and distribution of the mentioned medicinal species with the botanists who were part of the team of researchers in the study. Observation points were those where any of the searched plant was located. At each observation point the sought plant species was identified by the key informants, described and identified by botanists using experience and guide books. Voucher specimens of each species were collected and dried, sorted and verified at the National herbarium of Tanzania (NHT) in Arusha. The described information involved the location, plant life-form and vegetation type or habitat.

Data Analysis

Descriptive statistics was used to summarize data from household survey questionnaire. For in-depth interview, observation and FDGs, sociological and anthropological methods were used to analyze data. Of the entire plant species, we reported plant species that were used by at least one percent of the number of people for each tribe for medicinal purpose. The resulting list of medicinal plants was then used to determine the proportion of use.

RESULTS

Socio-demographic characteristics of respondents

A total number of respondents from the households were 105; and of these 51 (48.6%) were in Ngorongoro (21 in Sonjo, 30 in Maasai), 42 (40%) in Mbulu (20 Hadzabe and 22 Iraqw) and 12(11.4%) in Hanang (3 Mbulu and 9 Datoga). In the household surveys the respondents were composed of male and female ranging from youths (above 18) to elderly people above 45 years old, whereas only elderly people both males and females were engaged as key informants.

Medicinal plants reported

The total number of 131 species in 46 families of medicinal plant species were identified as commonly used for medicine by local communities in Northern Tanzania. The number of species mentioned by each ethnic group differs; the highest number was reported by Maasai in Ngorongoro, while the Hadzabe, Iraqw and Tatoga were similar (Table 1).

Table 1: Number of medicinal identified in Ngorongoro, Mbulu and Hanang Districts in northern Tanzania

S/N	Species	Proportion (%) of people mentioned the species					Total Proportion
		Hadzabe	Iraqw	Maasai	Sonjo	Tatoga	
1	Harrisonia abyssinica Rutaceae	-	-	2.2	4.4	-	6.6
2	Xanthoxylum chalybeum Rutaceae	-	-	4.1	1.2	-	5.3
3	Turrea nilotica Meliaceae	-	-	3.5	0.6	-	4.1
4	Warburgia salutaris Canellaceae	-	-	1.7	1.9	-	3.6
5	Salvadora persica Salvadoraceae	-	-	3.5	-	-	3.5
6	Acacia drepanolobium Fabaceae	-	-	3.4	-	-	3.4
7	Acacia nilotica Fabaceae	-	1.0	1.7	0.6	0.1	3.4
8	Combretum molle Combretaceae	-	-	0.5	2.9	-	3.4
9	Cassia abbreviata Fabaceae	1.6	0.2		0.1	0.2	2.3
10	Maesa lanceolata Primulaceae	-	-	2.1	-	-	2.1
11	Rhamnus staddo Rhamnaceae	-	-	2.1	-	-	2.1
12	Myrsine africana Myrsinaceae	-	-	-	2.1	-	2.1
13	Carissa spinarum Apocynaceae	-	-	0.8	1.1	-	1.9
14	Albizia anthelhmintica Fabaceae	-	-	1.8	-	-	1.8
15	Aloe secundiflora Aloaceae	-	-	1.7	-	-	1.7
16	Solanum incanum Solanaceae	-	-	1.0	0.2	0.5	1.7
17	Pappea capensis Sapindaceae	-	-	1.6	-	-	1.6
18	Commiphora schimperi Burseraceae	1.3	-	-	0.1	0.1	1.6
19	Euphorbia candelabrum Euphorbiaceae	-	-	1.5	-	-	1.5
20	Euclea divinorum Ebenaceae	-	1.0	0.4	0.1	-	1.5
21	Euphobia heterochroma ssp heterochroma Euphorbiaceae	-	-	1.3	-	-	1.3
22	Strichnos sp Loganiaceae	-	-	-	1.3	-	1.3
23	Acacia tortilis Fabaceae	-	-	1.2	-	-	1.2
24	Vepris nobilis Rutaceae	-	-	1.0	0.2		1.2
25	Plumbago zeylanicum Plumbaginaceae	-	-	1.1	-	-	1.1
26	Albizia harveyi Fabaceae	-	-	1.0	-	-	1.0
27	Osyris lanceolata Santalaceae	-	-	1.0	-	-	1.0
28	Rhamnus prinoides Rhamnaceae	-	-	1.0	-	-	1.0

Using the cut line of at least one percent proportion of people group who mentioned the plant species for medicinal use in each ethnic, 28 species (21.4%) in 19 families were mentioned by at least one percent people (Table 2). The leading among the 28 species were (total proportion out of 21.4 is shown in brackets) *Harrisonia abyssinica* (6.6%) followed by *Xanthoxylum chalybeum* (5.3%), *Turrea nilotica* (4.1%) and *Warburgia salutaris* (3.6%). All these species were mentioned by Maasai and Sonjo tribes. Two species were used by four ethnic groups out of the total five; these included *Acacia nilotica* (Iraqw, Maasai, Sonjo and Tatoga) and *Cassia abbreviata* (Hadza, Iraqw, Sonjo and Tatoga) (Table 2). There were also two other species which were used by three out of the five tribes: *Solanum incanum* (Maasai, Sonjo and Tatoga) and *Euclea divinorum* (Iraqw, Maasai and Sonjo). Nine species were used by both Maasai and Sonjo, four species by Sonjo and Tatoga, two species by Iraqw and Maasai as well as only one species was used by both Hadzabe and Iraqw.

Table 2: The 28 species in 19 families mentioned by at least 1% people in each ethnic group

District	Ethnic group	Number of plant Families	Number of plant Species commonly used	% of 131 species
Mbulu	Hadzabe	19	31	24
Mbulu and Hanang	Iraqw	15	31	24
Ngorongoro	Maasai	31	58	44
Ngorongoro	Sonjo	28	53	40
Mbulu and Hanang	Tatoga	16	30	23

Ailments treated and Plant parts used

A total of 15 diseases were commonly treated by traditional medicine in the area of the study. The highest proportion of people (13%) used medicinal plants to treat abdominal pain and malaria (11%). Some were used against the following eight human ailments: cough (7.1%), Fever (5.8%), Back pain (4.5%), Body pain (4.4%), STI (4.1%) Pneumonia (3.8%), Joint pain (2.9%), Diarrhea (3%), Flu (2.58%), Chest pain (2.58), Blood infection (2.2%), Indigestion (2%) and body weakness (1.63%).

Plant parts used

The usage of different plant parts was variable among the tribes. Roots and barks were commonly used parts by each ethnic group, roots being the mostly useful plant parts, followed by barks (Figure 2). Leaves and stems were uncommon, however, all tribes used mixtures of different parts, bu this was common strategy by Maasai and Sonjo.

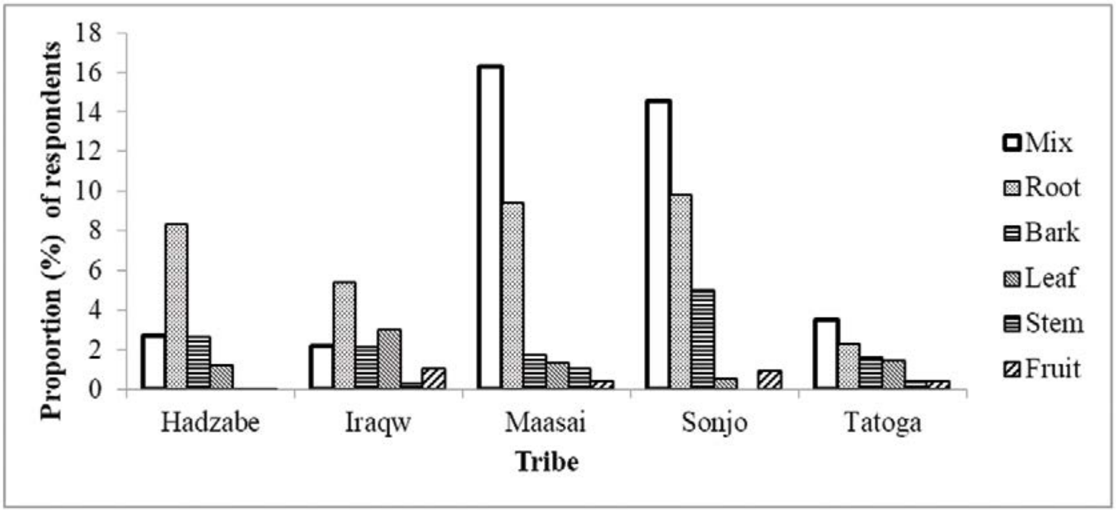

Figure 2: *Variation in the use of plant parts among the five tribes in Ngorongoro, Mbulu and Hanang Districts*

DISCUSSION

The collected data from the study area were analysed and presented. The presented results indicate that communities in Ngorongoro and Mbulu Districts are highly knowledgeable of medicinal plant species. A total of 131 species are frequently used to treat more than 15 diseases and conditions, with a clear contrast existing in ethno botanical knowledge among the different ethnic groups. The large number of species recorded highlight to a dependence on a wide diversity of plant species to treat various ailments and also to the existence of a substantial amount of ethno botanical knowledge on herbal plants among communities in northern Tanzania. Comparing information from previous surveys in the same communities, the number of common medicinal plants recorded from the present study is largely lower than the number reported by others for Maasai people (Searle 1999), Sonjo (Smith 1993), and Hadzabe (Unpublished data, Hamza *et al.,*2015); but was relatively higher than those reported for Iraqw (Albayaty 2011, Al–Douri 2014). Such differences may reflect changes in culture and climate. Despite the differences in the number of species reported, the results for this study give light that local people in northern Tanzania are endowed with ethno botanical information on which they depend for their day to day for primary health care needs. The present results are in line with observations that traditional medicine is commonly used to treat or prevent diseases and chronic illness and to improve quality of life (GITSH 1997, WHO 2003), and match conclusions by Kayombo *et al.*, (2013), that medicinal plants are still having great prospects on healthcare of local communities in Tanzania.

The findings from the present study also have clearly demonstrated that the different ethnic groups living within the same geographic landscape can interact with environmental resources. These interactions result into divergences and convergences of ethno botanical strategies among the groups with respect to the use of 131 plant species (more especially the 28 highly used species) in the area. Studies of quantitative approaches to a range of ethno- botanical issues have shown that local knowledge is being moderated by cultural history among ethnic groups, which has shaped peoples' use of their natural environment, fostering resilience during periods of plant resource scarcity such as during the dry seasons (Quave and Pieroni 2015). Maasai and Sonjo showed higher homogeneity (convergence) by having the highest number of species that they use for medicinal purposes within their respective culture, the possible reason could be that the two tribes live in close proximity and interact within similar landscapes, leading to a higher possibility for cultural exchange among the two tribes. Among many factors that influence cultural exchange between multilingual groups include living in close proximity (Georgian and Emshwiller 2013).

Furthermore, the present results indicated that local knowledge of medicinal plants in the treatment of various ailments still exists in villages surveyed and appear to play an important role in primary health care services in remote rural areas in the study area. This allows for identifying many high value medicinal plant species that have high potential for economic development in the country. The findings suggest the need to preserve this knowledge of medicine by proper documentation and identification of specimen and especially emphasizing on innovations in the pharmaceutical industries. The fact that higher proportions of medicinal plants are used to treat abdomen and malaria ailments could be attributed to the high prevalence of the diseases/ill health conditions in the area. Stomach illness is usually an indication that people in these areas have tangible experience with their environment and possibly poor access to clean and safe water, thus leading to waterborne diseases that generally cause stomach illness (Gleick 2002). Access to adequate supplies of safe water for drinking and food preparation is an unmet need in rural areas in Tanzania, including northern Tanzania (Jiménez and Pérez-Foguet 2010, De Palencia and Pérez-Foguet 2011).

Among major issues of concern that can be learned from this study is the question of sustainable conservation of indigenous medicinal plants in their area of occurrence. The findings from this study indicated that the use of most medicinal plants mostly involve roots and barks, which suggests a more destructive usage. The details on why roots are preferred most for medicine than other plant parts were not the focus of this study. However, it could be a result of the long experience by the local people with plants in terms of their performance in treating various diseases. Notwithstanding studies involving chemical and biological investigation to authenticate such experiences by the local people could help in suggesting proper usage of medicinal plant resources. For example, a chemical and biological study by Jena *et al*., (2017), to compare the anti-inflammatory and analgesic effect of different parts, they revealed close similarity between the roots and the leaves and the results led to a suggestion to use leaves instead of roots.

CONCLUSION

The study has revealed a significant contribution of medicinal plants knowledge to the livelihood and health security of communities in northern Tanzania. The wealth of this ethno botanical knowledge is evidenced by the great number of plants recorded for treating various diseases. This knowledge offers a basis for prioritizing further phytochemical and pharmacological studies of medicinal plants that are used to treat chronic diseases. In northern Tanzania all groups are knowledgeable, indicating their knowledge potential in the daily performance of traditional medicine. It is therefore recommended that the ethno botanical knowledge of medicinal plant resources in northern Tanzania be recognized and preserved to improve and ensure the future effectiveness of the primary health care system. Furthermore, due to the great interest in studying medicinal plants, there is a need to carry out phytochemical and pharmacological studies for most unstudied but potential species to validate usage, find new pharmaceuticals, increase confidence among users and contribute to the development of the traditional medicine sector.

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SOCIAL-ECONOMIC SURVEY OF THE USE OF EDIBLE WILD ORCHIDS IN MPANDA DISTRICT, KATAVI REGION

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ABSTRACT

All Orchid species are protected by the Convention on International Trade in Endangered Species (CITES). Tanzania is a wild orchid biodiversity hotspot. However, despite its importance, knowledge on their distribution and social, ecological and economic values is very limited. This poses a major threat to their survival. This study aimed at assessing the social and economic values and communities' efforts towards conservation of edible wild Orchids as well as their current markets in Mpanda District, Katavi Region. The study was conducted in three purposively selected villages that favour the growth of orchids (Vikonge, Isenga and Bugwe). Questionnaire surveys, Focus Group Discussions, Key Informant Interviews and direct observations were used as key tools for data collections. Results indicated that 86% (n=99), of the respondents, had no knowledge about edible wild orchids. A total of six wild edible orchid species were recorded in vernacular names; Chikanda (Fipa)/Videnesi (Hutu)/ Machikanda (Bende), Chisekelela (Fipa), Matiu (Fipa), Nalumbwa (Fipa), Malembwe (Fipa), and Manji (Fipa). Edible wild orchids have a significant contribution to the household economy of the rural communities; they are mostly used as food and mainly during food shortage. It was also reported as among the important income generating crop due to increased market demand from neighboring countries such as Zambia and Malawi. In all three villages, women dominated the activities related to edible orchids (62%; n=99). Lack of knowledge on the ecological status, social and economic values at large, have hindered the conservation and protection of the species. The study recommends that Management authority and stakeholders in biodiversity conservation should start an intensive campaign to promote and support conservation awareness raising programmes to protect the species. Lastly, initiate strategies for conserving species , like propagation programmes so that it can be cultivated as other commercial crops.

Key words: *Edible wild orchids, social and economic values, Mpanda District*

INTRODUCTION

Orchids are mostly known for their beautiful flowers which make them a resource of great economic importance in the global horticultural industry (Mugasha *et al.,* 2005; Gattoo and Ahmad, 2013). The attractive colour and shape of their flowers has made them very popular and as a result, these plants have great ornamental value, in the Southern African region (Kasulo *et al*., 2009). All Orchid species are protected by the Convention on International Trade in Endangered Species (CITES), which requires certification of plants crossing international borders (IUCN, 2001; Mapunda, 2007).

Tanzania is one of a wild orchid biodiversity hotspot (Chale & Price, 2009). Community based wild orchid has a long history as orchids are closely associated with the socio economic culture of the local people (Gattoo & Ahmad, 2013). In Tanzania, "edible Orchids" are terrestrial species growing wildly, particularly in mountainous parts of the Southern Highlands, where their tuberous roots are dug up from the ground for human consumption (Hamisy, 2005).

Orchid tubers are reported to be used in different ways (Lalika *et al.,* 2013). Traditional pattern of use of orchids changed with the introduction of an international market for wild orchid tubers in southern African countries, such as Zambia creating increased demand for Tanzanian orchid tubers (Chale & Price, 2009). In Tanzania, Zambia, and Malawi, orchids are mostly important for their tubers which are used as a source of food and income, as are traded within and across the countries (Nyomora, 2005; Kasulo *et al.,* 2009). Edible orchid tubers have traditionally been consumed as a midday snack food (Chale & Price, 2009). In Zambia, the tubers from the orchid genera *Disa, Habenaria* and *Satyrium* are the main ingredients of "*chikanda*", a popular meatless sausage (Jumbe *et al.* 2007). Some orchids of Tanzania provide edible tubers from which a staple food known as 'Kikande', 'Chikanda' or Kinaka is made that is consumed by the Ngoni, Fipa, Nyiha and related tribes in neighbouring Zambia (Davenport & Ndangalasi, 2003). However, despite the importance of orchids to wide range of communities, knowledge on their distribution and social, ecological and economic values is very limited. This poses a major threat to their survival.

High market demand of edible orchids in Zambia is threatening orchid populations in Tanzania (Davenport & Ndangalasi, 2003). It is estimated that between 2.2 and 4.1 million orchid plants consumed annually in Zambia originate from Tanzania (Davenport & Ndangalasi, 2003). Despite that orchids are protected by CITES, it is now well known that high market demand in the neighboring countries and the illegal trade in wild edible orchids contributes to their further endangerment yet little is understood about the gatherers themselves (Chale & Price, 2009). Many areas in southern highlands of Tanzania where edible orchids were plenty had indicated a declining trend due to overexploitation. Currently in these remote areas of Southern highlands, their uses and threats that include their socio-economic values to the large extent are not well documented or known. This study thus aimed at determining social- economic values of edible wild orchids in the study area. Furthermore, the study identified key species used, their local distribution in the area, challenges that hinder conservation initiatives practiced and how local community participate to rescue the species in use.

METHODS

The study was conducted from June to July 2016 in Mpanda District, Katavi Region in western Tanzania. Primary data collection was obtained through questionnaire survey, Focus Group Discussions (FDGs) and Key Informant Interviews (KIIs). The aspects covered in these tools focused on traditional uses of edible orchids, gender roles in activities related to edible Orchids, marketing of edible orchids, edible orchid species utilized and their preferences. Other information collected were on contribution of edible orchids towards household economy, strategies/efforts of local communities on Orchid's conservation and lastly challenges facing local communities on conservation of edible orchids.

The study was conducted in four purposively selected villages that favor the growth of orchids namely; Vikonge, Ifumbura, Isenga and Bugwe Villages in Mpanda District. A total of 99 households in three villages were interviewed through questionnaire survey. Data were analyzed qualitatively and quantitatively. Statistical Package of Social Science (SPSS) was used to analyze data and results were presented in form of tables, percentages and graphs.

RESULTS

Knowledge of local communities toward edible species of wild orchids

In all representative sample (n=99), 87% of the responds had no knowledge while 13% had knowledge of edible species of wild orchids (Table 1). In respect to that, 28, 40 and 18 individuals in Vikongwe, Isenga and Bungwe Villages respectively had no knowledge, while 5, 2 and 6 individuals respectively, had knowledge on edible species of wild orchids (Figure 1). The villages respondse has significant variation in terms of knowledge in edible species of wild orchids (Pearson χ^2=5.6, df=2, p=0.05, n=99). This finding signifies that lack of knowledge of edible orchids to local communities is a big challenge towards its sustainable utilization and conservation which needs special attention to be addressed.

Table 1: knowldge about wild orchid

Response	Frequency	Percent
Yes	86	86.9
No	13	13.1
Total	**99**	**100.0**

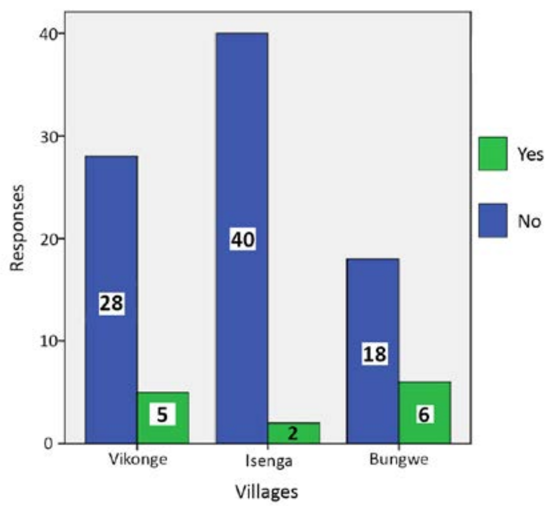

Figure 1*: Local community knowledge on wild edible orchids in three villages of Mpanda District.*

Species of edible wild Orchids utilized by communities and preferences

A total of six wild edible orchid species were recorded in vernacular names during survey period; i) Chikanda (Fipa)/Videnesi (Hutu)/Machikanda (Bende), ii) Chisekelela (Fipa), iii) Matiu (Fipa), iv) Nalumbwa (Fipa), v) Malembwe (Fipa), and vi) Manji (Fipa). In all surveyed areas Chikanda (refered as common orchids) was most preferred followed by Matiu due to its favorite taste and aroma. Chisekelele reported to have chilly taste. These orchids were reported to be found in different places in the surveyed villages especially in wetland areas (Table 2). Although, orchids are still found in these places but generally the amount and places where orchids are currently found has decreased compared with previous year due to increased human activities in wetlands, especially agriculture and livestock keeping.

Table 2: Important areas where orchids are found in villages

SN	Name of villages	Ward	Places where orchids are found within the village	Places where orchids are found outside the village
1.	Vikonge	Tongwe	- Lukolesala mbuga: Mtemi area close to Mzee Cosmas and mama Mizengo areas - Saba saba area a bit far from the village	- Bugwe - Busongola, Bulamata and Isenga (Mishamo ward) - Misanga area at Luhafu wetland
2.	Ifumbira	Mishamo	- Sangwa wetland - Isinde wetland - Near Salanda hills - Sige sige wetland - Mlasi wetland near Mugasa river	- Near Lugufu river - Bugwe - Isenga
3.	Isenga	Mishamo	- Msiasi wetlands - Kabika Spring area - Kaseba Wetland - Kafulu wetland - Lusaka wetland	- Bugwe - Kabwe Bulamata wetlans - Isukaminso wetland - Busimbili wetland
4.	Bungwe	Tongwe	- Kachoma wetlands - Itaba wetland - Maparamane wetland	- Lusaka wetland

Traditional uses and trade of edible wild Orchids and its contribution to household economy

Edible wild orchids were reported to be used mostly as traditional food. Orchids were eaten as snacks or sauce for other main dishes like *"ugali"* (stiff porridge) or rice. Also, it was reported that one species of orchid is used as deworming herbal food, which need to be confirmed by specialists. Major markets of raw edible orchids that were reported include Mpanda, Sumbawanga, Mbeya, Tunduma and Zambia. The price of raw edible wild orchids ranges between TZS 300,000/= to 700,000/= per bag. In these areas sliced cooked orchids were sold in the local markets including village bars. The price of cooked sliced edible orchids ranges between TZS 200/= to 700/= per piece.

Income generated from Orchids can be used as capital for other income generating activities including small business, agriculture, and livestock keeping. Physical assets accrued from sales of orchids that were recorded in the surveyed villages included; bicycles, iron sheets, and cooking utensils. In case of human assets, income generated from sales of orchids enabled respondents to pay school fees for their children and medical services for their families. Social benefits included food, purchase of clothes and paying for other basic needs for their family members. These benefits indicate that edible wild orchids have significant contribution to the livelihoods of households in the rural communities.

Gender roles in all activities related to harvesting, processing, use, trade and conservation of edible wild Orchids

Results indicated that women dominate activities related to edible wild orchids (62.8%), while only 27.2% of men participate in these activities (Figure 2). Women were reported to participate in all activities from harvesting to trade. Men were reported to participate in harvesting, packaging, use and trade of raw orchids only. Few women were reported to participate in harvesting of edible wild orchid compared to men due to long distances to the wetlands where these orchids are found. Participation of youth was very low (23.2%) in activities related to edible wild orchids. Though to less extent but youth were reported to participate in harvesting, processing, use, trade of edible orchids. This observation implies that men participate mostly in other income generating activities which generate more money like agriculture and livestock keeping. But participation of both genders and youth in all activities related to wild edible orchids will enhance possibility of their livelihood improvement.

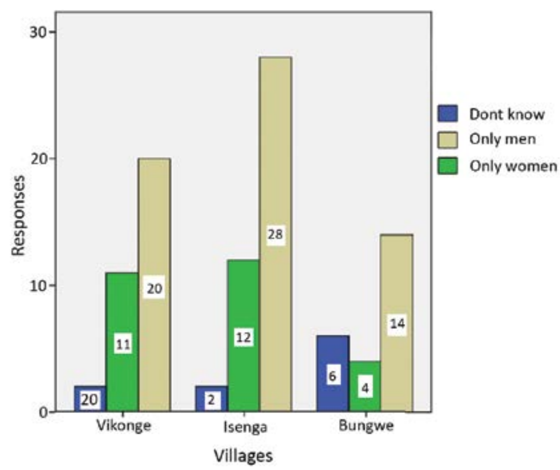

Figure 2: *Gender participation in activities related to edible wild orchids*.

Strategies/efforts of local communities on Orchids conservation

In all surveyed areas results indicated that currently, there are no specific strategies/efforts for conservation of edible orchid species. However, it was mentioned that in some villages they have by-laws for conserving wetlands, which are also not much implemented. This result indicates that in order for this plant species to be effectively conserved there is need for urgent and concerted efforts of all key stakeholders in conservation to protect the species.

Challenges facing local communities on conservation of edible orchids

The main challenges facing local communities on conservation of edible orchids is lack of knowledge on the status of the plant as an endangered species, uses, values and its importance to the ecosystem. Other challenges include;

- Degradation of wetlands areas where most of orchids grow caused by livestock grazing and agriculture activities (rice farms).
- Over exploitation of orchids exacerbated by lucrative market demand from neighboring country (Zambia).
- Weak law enforcement for protection of wetlands and rivers.
- A local taboo that considers orchid business (use and trade) as poor men's affair.
- Unreliable market price (price depends on the buyer's decision).

All these are considered to contribute negatively towards promotion of conservation of the orchid species.

CONCLUSION

In general, majority of local communities in Mpanda District had no knowledge of edible species of wild orchids. Edible wild orchids play a significant role to the livelihoods of the rural communities in the study area. Also, women dominate activities related to edible orchids. But this species is threatened in study area due to increased market demands and human population with rapid change in land use Thus, the species need an immediate conservation action to be taken.

Lessons learnt

Local communities participating in orchids harvesting are not aware on the values and uses of the edible orchids. They participate in this business only for the income which leads to over exploitation of this resource and no conservation measure in taken on board at all.

RECOMMENDATIONS

We recommend that management authorities and stakeholders in biodiversity conservation should plan and implement comprehensive initiatives to enhance conservation and sustainable utilization of edible wild orchids. Feasibility study on domestication of economically valuable orchid species should also be considered.

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COMBINED EFFECTS OF DROUGHT AND SHADE ON THE GROWTH OF ACACIA SEEDLINGS. PRELIMINARY RESULTS

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ABSTRACT

Seedling establishment is among the challenging stage in the life history of many plant species due to variability in resource availability at microsite level across environmental gradients. One fundamental question in ecology is how do seedlings respond to a combined effect of drought and shade? This is an important area of concern because many studies suggest that climate change scenarios are expected to change water availability. Applying a randomized block design, we conducted an experiment to assess the responses of A. robusta and A. tortilis seedlings to combined effects of varied moisture and light levels. We found responses that varied within and between species. For within species, both species under high moisture and full light condition resulted in higher mean seedling heights than their counterparts grown under low moisture but similar light availability. However, under the same high moisture and light availability, seedlings of A. tortilis maintained higher growth compared to those under high moisture but in shade conditions. We also report that, A. tortilis and A. robusta respond differently to resource interactions with A. tortilis showing more plasticity in growth and biomass allocation than A. robusta which may help in understanding of their contrasting distribution in the Serengeti National Park.

INTRODUCTION

Seedling establishment is among the perilous stage in a life history of many plant species due to variability in resource availability at microsite locations (Eriksson & Ehrlén, 1992; Setterfield, 2002). Microsite suitability differs across environmental gradients, and a successful establishment depends on the ability of a growing seedling to adopt and efficiently utilize the available resources (Barnes, 2001, Stave *et al.,* 2006). Shade and drought affect plant growth in various ways. For example, while drought affects cellular processes leading to diminished growth (Bartlett *et al.,* 2012), shade reduces photosynthetic performance (Dai *et al.,* 2009) which eventually affect plant productivity.

One fundamental question in ecology is how do seedlings respond to a combined effect of drought and shade? This is an important area of concern because studies suggest that climate change scenarios are expected to change water availability (Sheffield & Wood, 2008, Dai 2013) therefore affecting ecosystem productivity and species distribution (Ma *et al.,* 2015; Yu *et al.,* 2017). Previous studies have established two major hypotheses regarding seedling growth as a function of combined drought and shade namely; *trade-off* and *facilitation* hypotheses. *Trade-off hypothesis* suggests that the response of plants to combined effects of drought and shade is shaped by a trade-off between drought and shade tolerance traits (Smith & Huston, 1989). This hypothesis assumes that competing for light requires a seedling to invest more into shoot growth while competing for soil moisture requires investment into below ground biomass. *Facilitation hypothesis* suggests that the negative effect of drought will be reduced by shade if seedlings are growing under shaded microsites due to lowered air temperatures (Holmgren *et al.,* 1997; Holmgren *et al.,* 2000). However, these hypotheses have been tested on forest species with less data from savanna species.

Savannas are characterized by water scarcity and their understory is dominated by grasses. This characteristic pose shade and drought stress to growing seedlings. However, it is unclear on how seedling growth in these conditions could be affected by a combination of resource scarcity. Moreover, the occurrence of drought and shade is not mutually exclusive *i.e.* a plant is not expecting one stress at a given time. The question here is, what morphological strategies do savanna species use to allocate resources and maximize survival under stress? Most researches in savanna ecosystems on seedling establishment tend to focus on the response to changes in one condition in the absence or keeping the other conditions constant (Abari *et al.,* 2012; Kebbas *et al.,* 2015; El Atta *et al.,* 2016). The effect of one condition provide insufficient information to understand natural patterns given the simultaneous changes in key resources along environmental gradients (Holmgren, 2000).

The goal of this study was to assess how combined effects of drought and shade affect the growth and biomass allocation in *Acacia (Vachellia) robusta* and *A. tortilis* species by testing whether they fall under either *trade-off* or *facilitation* scenarios. Our hypotheses were anchored in changes in seedling growth and biomass allocation patterns as a function of soil moisture and light levels interactions. We addressed 2 questions: (1) Is the growth response of *A. robusta* and *A. tortilis* to shade and drought interactions similar or different and (2) What hypotheses (*trade-off* vs *facilitation*) best explain patterns in growth and resource allocation strategies?

MATERIALS AND METHODS

Study species and experimental setup.

In this study, we used seeds of *A. robusta* and *A. tortilis* species sourced from the Serengeti National Park (SNP). The two species were selected because of (1) their widespread spatial distribution and (2) relative opposing dominance across the Serengeti's rainfall gradient, with *A. robusta* dominating the mesic and *A. tortilis* the dry end of the ecosystem (Rugemalila *et al.,* 2016). Seeds of both species were manually scarified, and planted in a 2:1:1 potting mixture of an organic (Metromix 360 -P, Marysville, OH), sand and clay soils. A fraction of mixed soil was put in germination trays for seed germination. Watering on the germination trays was monitored to ensure optimal soil saturation for seven days. Seedling pots were prepared by filling with ~2 kg of sieved and homogenized soil, then watered until water dripped through the pot base holes. The experiment consisted of 3 levels of soil moisture treatments (80%, 60% and 40%) of soil the water holding capacity and 3 levels (0%, 50% and 75%) of shade. We employed a randomized block design to assign species and treatment levels. We used saturated pot soil mass to compute for the mass each pot should weigh when soil moisture content reaches the desired water treatment level. Pots were labeled for species, treatment type and pot weight then randomly placed on blocks.

Shading was constructed using 3/4-inch light PVC pipes joined in a 2x1x1 m rectangular shape in which a UV resistant fabric shade cloth was applied in the order of (no cloth, one layer, and layer) for 0%, 50% and 75% shade treatments respectively. Germinated seedlings for each species were then transplanted into the pots, but watering was not performed until each pot reached the desired weight for each treatment level.

Growth and morphology data

Pots were inspected regularly and weighed using OHAUS Adventurer Pro analytical balance (Pine Brook, NJ), then watered each time pot weight fell below the assigned mass. We collected data on seedling height, shoot length and leaf production for 2 months.

Data analysis

Data analysis was performed in R statistical language (Ihaka & Gentleman, 1996; R Development Core Team 2011). The general approach involved preliminary data organization into two categories of growth and biomass allocation followed by inspection for normality prior to further analysis.

Seedling growth

Seedling growth involved assessment of aboveground changes in shoot height (variable *HEIGHT*) and relative growth rate (*RGR*). The final seedling growth dataset consisted of records for a day when data were collected (variable *DAY*), species identity (*SPECIES*), allotted block (*BLOCK*), treatment levels (*MOISTURE* and *SHADE*) and *HEIGHT*. This dataset was aggregated to obtain mean value for growth parameter per *DAY*, *SPECIES*, *BLOCK* and treatment levels. The variation in *RGR* in seedling height over time was estimated using the following general formula,

$$RGR = \frac{\ln H_2 - \ln H_1}{T_2 - T_1}$$

Where; T_1 and T_2 represents time intervals between height measurements and *InH* represents the natural log for height.

Biomass allocation:

We first calculated biometric indices to assess how seedlings optimize biomass allocation to leaves, stems, and roots as a function of changes in microsite condition. The indices calculated include; total dry biomass (*TDB*), root-to-shoot ratio (*RSR*; *root dry mass (g) / shoot dry mass (g)*), leaf -to-stem ratio (*LSR*; *leaf dry mass (g)/ stem dry mass (g)*) and leaf mass area (*LMA; leaf dry mass (g) /leaf area* (cm^2)). All our proportional values for *RSR*, *LSR*, and *LMA* were standardized using logit transformation (Baum, 2008; Warton & Hui, 2011) before further statistical analysis. In each analysis, to understand the interactive effect of *MOISTURE* and *SHADE* on growth and biomass allocation, we developed four competing models and employed model selection approach using Akaike Information Criterion (*AIC*) to compare and select the best model. As our goal was to understand whether the two-species responded differently or similarly to environmental stress, during model development, we explicitly considered predictor interactions in our models in which *SPECIES*, *MOISTURE* and *SHADE* were specified as fixed factors while *DAY* and *BLOCK* were specified as random factors. We fitted candidate models using *lmer* function in the *lme4* package (Bates *et al.,* 2007) in R environment. The significance between group interactions were tested using *Anova* function implemented in the R-package *car* (Fox, 2002). *Post – hoc* analysis was performed on models with significant interactions only, applying a Tukey's test by *holm's* method (Holm, 1979; Aickin & Gensler, 1996) and a *glht* function implemented in the R-package *multicomp* (Hothorn *et al.,* 2008).

RESULTS:

Seedling height growth:

Analysis for seedling height growth showed different responses to moisture and shade treatment between and within species which were encapsulated in a significant three - way interaction between SPECIES, MOISTURE and SHADE (Table 1).

Within species:

Post – hoc analysis for multiple comparison of means revealed that seedlings of *A. robusta* and *A. tortilis* grown in high moisture soils exposed to full light resulted in higher seedling heights than those grown in low moisture soils exposed to full light ($P < 0.0001$) (Fig.1a). However, while the seedlings of *A. robusta* grown under a combination of high moisture and shade condition did not differ in height when compared to those under low moisture and shade conditions; for *A. tortilis* under high moisture and shade conditions resulted in shorter heights compared to those under low moisture – shade conditions ($P < 0.0001$) (Fig. 1a). Moreover, there was no significant difference in *A. robusta* when comparing seedlings grown under high moisture but different shade levels. On the other hand, *A. tortilis* seedlings grown under shaded wet soils (Fig. 1a) had significantly shorter heights than those grown under light exposed wet soils ($P < 0.0001$). Additionally, while *A. robusta* seedlings grown under shaded dry soil resulted in significantly higher heights than those under light exposed dry soils ($P < 0.0001$), there was no significant difference in *A. tortilis* under these treatments ($P = 0.761$).

Table 1: Model fits (AIC, the Akaike Information Criterion) for the effect of SPECIES, SHADE, MOISTURE and their interaction on seedling height, RGR, Total seedling dry biomass, RSR, LSR and LMA using generalized linear mixed-effects models.

Variable	Fixed effect model	△AIC	DF
Height	Intercept	131.8	4
	Spices x Shade	58.7	7
	Spices x Moisture	76.7	7
	Spices x Shade + Spices x Moisture	53.3	9
	Spices x Shade x Moisture	0.0	11
RGR	Intercept	0.0	3
	Spices x Shade	2.5	6
	Spices x Moisture	13.8	6
	Spices x Shade + Spices x Moisture	22.5	8
	Spices x Shade x Moisture	24.7	10
Total Biomass	Intercept	7.6	3
	Spices x Shade	0	6
	Spices x Moisture	11.2	6
	Spices x Shade + Spices x Moisture	10.2	8
	Spices x Shade x Moisture	10.7	10
RSR	Intercept	0	3
	Spices x Shade	5.8	6
	Spices x Moisture	10.7	6
	Spices x Shade + Spices x Moisture	9.5	8
	Spices x Shade x Moisture	17.6	10
LSR	Intercept	1.3	3
	Spices x Shade	0	6
	Spices x Moisture	10.7	6
	Spices x Shade + Spices x Moisture	6.9	8
	Spices x Shade x Moisture	17	10
LMA	Intercept	0	3
	Spices x Shade	1.2	6
	Spices x Moisture	5.2	6
	Spices x Shade + Spices x Moisture	8.8	8
	Spices x Shade x Moisture	11.2	10

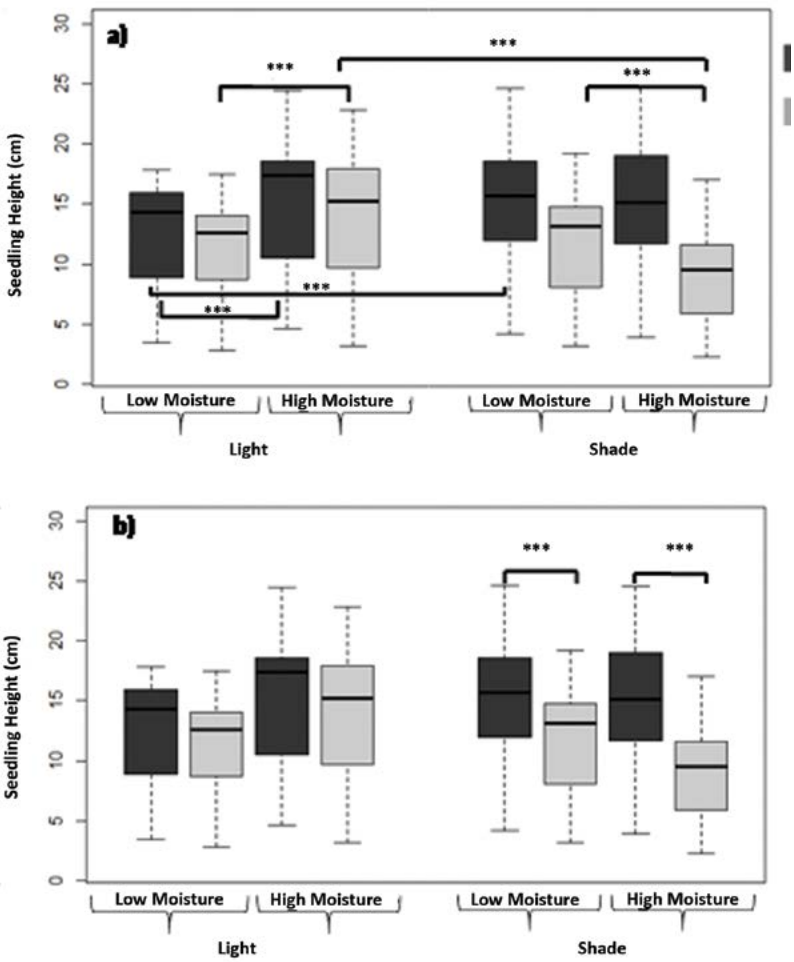

Figure 1: *Seedling mean height growth as a function of changes in moisture and Light levels. a) Within species response and b) between species responses to different combination of moisture and light levels. Stars (*) shows statistical significance levels in which P < 0.0001: ***; P < 0.01: **; P < 0.05: *; P > 0.05: no star.*

Between species:

Here, we focus on comparing the two species under similar growth conditions. Our results show that, when both species were subjected to similar conditions of either high moisture soil - full light or low moisture - full light combinations, seedling heights were not significantly different (*P > 0.05*). However, when growing conditions were a combination of either low moisture and shade or high moisture and shade, *A. robusta* seedlings heights were significantly higher than those of *A. tortilis* (*P < 0.0001*) (Fig. 1b).

Relative growth rate:

Model selection approach suggested that the intercept model best fitted the data, meaning that no treatment effects on *RGR*. Therefore, no further analysis was done on these data.

Effect of shade on resource allocation

For *biomass allocation* analysis, model selection results showed that interactive m t in

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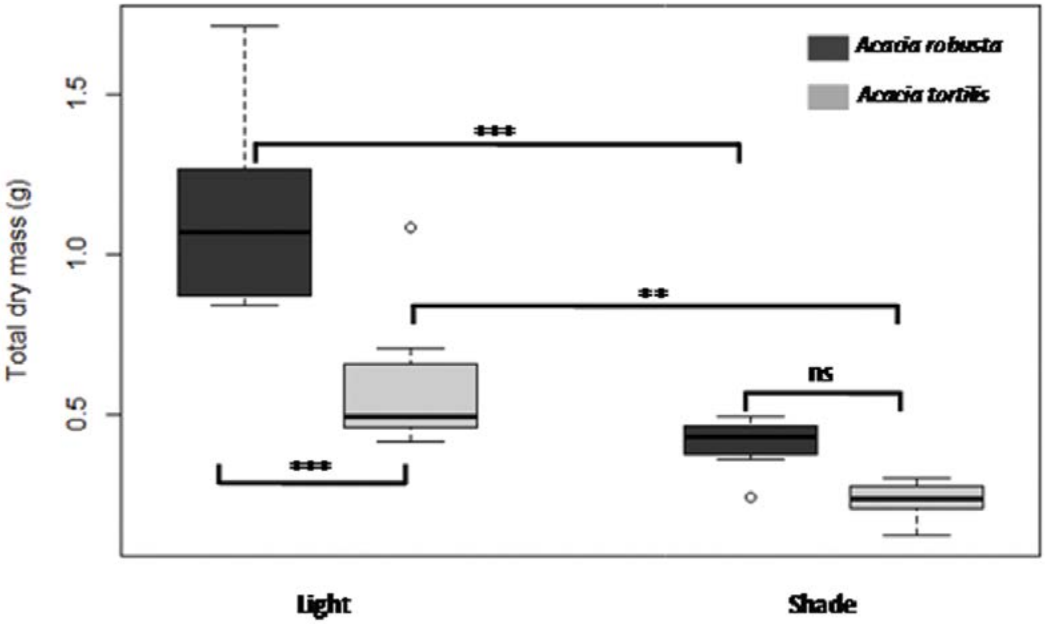

Figure 2: *Total seedling dry biomass as a function of species and light level interactions. Stars (*) shows statistical significance levels in which P < 0.0001: ***, P < 0.01: **, P < 0.05: *, P > 0.05: ns or no star.*

For *TDB, post – hoc* analysis showed that both species resulted in higher *TDB* under full light than under shade condition (*A. robusta*: *P < 0.0001*, *A. tortilis*: *P = 0.004*). However, between species comparison showed that while *A. robusta* under full light resulted in higher total dry biomass than *A. tortilis* under similar conditions (*P < 0.0001*), there was no significant difference when both species were grown under shade (P = 0.16) (Figure 2). *For RSR* and *LMA,* the interaction models did not improve fit over an intercept-only model, suggesting that neither moisture nor shade interacted with species to influence resource allocation to either shoots or roots or affect *LMA*, therefore *post – hoc* comparisons were not performed.

On *LSR, post hoc* comparison results showed variation in response to light levels within and between species. While *LSR* in *A. robusta* was not affected by light levels (*P > 0.05*) – Figure 3, *A. tortilis* under shade resulted in higher *LRS* values compared to those under full light condition (*P < 0.01*). Though, *A. robusta* under full light condition resulted in higher *LSR* than those of *A. tortilis* under similar conditions (*P < 0.001*), there was no significant variation when both species were grown under shade (*P = 0.24*).

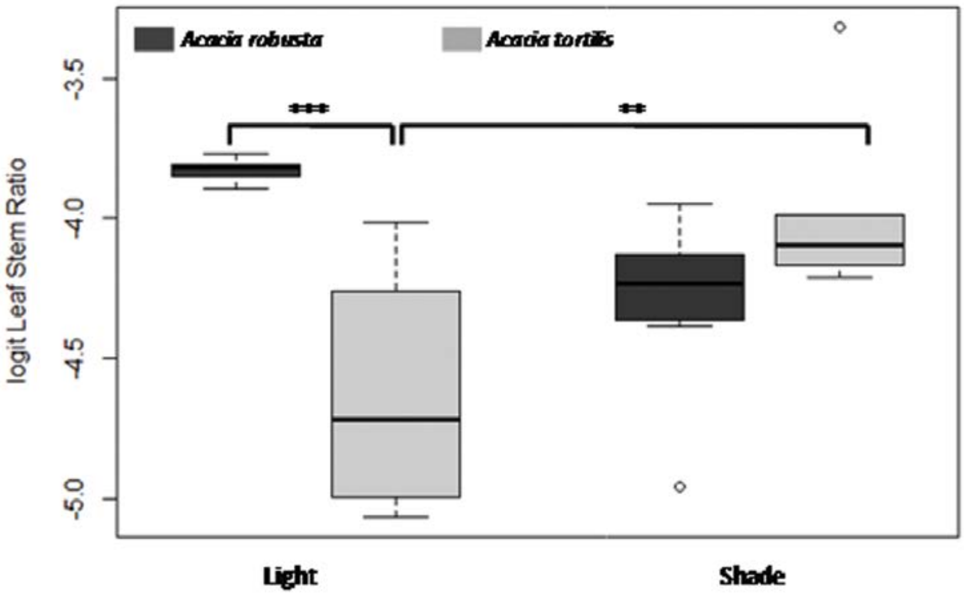

Figure 3: *Leaf Stem Ratio as a function of species and light level interactions. Stars (*) shows statistical significance levels in which P < 0.0001: ***, P < 0.01: **, P < 0.05: *, P > 0.05: ns or no star.*

DISCUSSION

This study assessed the responses of *A. robusta* and *A. tortilis* seedlings to combined effects of varied moisture and light levels. Our first question aimed at understanding if growth responses in *A. robusta* and *A. tortilis* to shade and drought interactions were similar or different. We found various responses within and between species. For within species, both species under high moisture and full light resulted in higher mean seedling heights their counterparts grown under low moisture but similar light availability. This pattern suggests that, to attain higher growth under full light, high moisture availability is important than low moisture (Fig. 1). However, under similar high moisture and light availability, seedlings of *A. tortilis* maintain higher growth compared to those under high moisture but in shade conditions. In this scenario, *A. robusta* seedlings did not respond significantly to change in light availability suggesting that under high moisture availability the absence of light will negatively affect seedling growth in *A. tortilis* than in *A. robusta.* Moreover, when both species were grown under shade cloth with different moisture availability, seedling growth in *A. tortilis* resulted in higher mean height under low moisture soils than under high moisture soils with no effect on *A. robusta* seedlings. This suggests that, under shaded environment, *A. tortilis* grows better when there is low moisture. When both species were grown under low moisture soils subjected to different light levels, only *A. robusta* responded to difference in light levels in which the seedlings grown under shade resulted in higher seedling heights compared to those under full light. These trends suggest that, *A. robusta* and *A. tortilis* respond differently to combination of moisture and light conditions.

Our second question aimed at understanding how *facilitation* and *trade-off* hypotheses explain the growth patterns in our species. Our results suggest that *A. tortilis* undergoes trade-off scenario due to its plasticity in response to light availability in which its growth patterns depended on the combination of soil moisture and light levels. With facilitation hypothesis, we look at the growth of both species under dry conditions in the presence or absence of light. Our results suggest the presence of *facilitation* by shade in *A. robusta* but not in *A. tortilis* when soil moisture is low. Previous studies on seedling establishment especially in *A. tortilis* suggested a strong reliance on moisture availability (Wilson & Witkowski, 1998), but independent of light conditions (Stave *et al.,* 2006). Our study shows a trade-off between moisture and light availability in which under high moisture and full light conditions, growth in *A. tortilis* is higher than when soil moisture is lowered and light kept available. However, under high moisture and shade conditions, seedling growth is lower when soil moisture is lowered and shade is maintained (Fig. 1).

In terms of *RGR,* we did not find interactive effects of moisture and light levels on *RGR*. Our results are not in consistence with Smith and Shackleton (1988)s' results in which *RGR* in *A. tortilis* was observed to be lower under shaded conditions. Other studies (Tomlinson *et al.,* 2014, Gignoux *et al.,* 2016) which compared *RGR* between forest and savanna species reported lower *RGR* for deciduous than evergreen species. We suggest that, lack of interactive effects of moisture and light levels on seedlings' *RGR* is explained by the moisture – light level *trade-offs* in *A. tortilis* and facilitation effects in *A. robusta* which might be translated as a strategy towards maximizing survival and resource utilization than growing faster or slower.

We also assessed the effect of moisture and light levels on *TDB, RSR, LSR* and *LMA* and found that under full light *A. robusta* resulted in higher *TDB* (Fig. 2) and *LSR* (Fig.3) than *A. tortilis.* Surprisingly, *RSR* and *LMA* which also denote trade-off due to limiting resources and light acquisition strategies respectively (Ma *et al.,* 2016) were not influenced by moisture and light level interactions. Studies suggest that, the response to drought stress in *Acacia* species dominating xeric sites is achieved through their rooting strategy and efficient root water uptake (Otien*o et al.,* 2005). In our case, we expected that the rooting strategy would be revealed by higher *RSR* for seedlings grown under dry conditions especially in *A. tortilis*. We suggest that, lack of these effects could be linked to the level of low moisture treatment in which 40% moisture level could be not dry enough to trigger these effects given the vast distribution of *A. tortilis* in dry ecosystems (Andersen *et al.,* 2016). Although we found no effect of light levels on *RSR* in both species, *A. robusta* under full light resulted in higher *LSR* than *A. tortilis* suggesting that, most of *A. robusta's* above ground biomass was invested in leaves than in stems. However, *A. tortilis* under light allocated more aboveground biomass in stems than leaves as mirrored by lower *LRS* under light than under shade. We suggest that, this trend is a strategy in *A. tortilis* for maximizing seedling anchorage because seedlings under full light tended to be taller than those under shade (Fig 1). Previous studies have suggested that increase in investment towards stem and less in leaves is as an supplementary response variable of the shade avoidance syndrome (Franklin, 2008) which also indicate morphology being more plastic than allocation. In general, our study contributes towards more understanding of the response of savanna species to combined effects of stress due to drought and shade. We have shown that, *A. tortilis* and *A. robusta* respond differently to resource interactions with *A. tortilis* showing more plasticity than *A. robusta* which may help in understanding of their contrasting distribution in the Serengeti National Park (Rugemalila *et al.,* 2016).

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UNDERSTANDING RANGELAND CONDITIONS THROUGH COMMUNITY-LED SOLUTIONS: A CASE STUDY FROM NORTHERN TANZANIA

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ABSTRACT

Climate change effects include unpredictable rainfall patterns and long periods of drought that drive water scarcity and erosion of topsoil, two elements that drive rangelands' productivity (Brown and Thorpe, 2008; FAO, 2009). This work focuses on the rangelands bordering the western slopes of the Mount Meru, in the Southern Acacia-Commiphora bush lands and thickets eco-region. This ecoregion, interspersed with patches of Serengeti Volcanic Grasslands, covers one fifth of Tanzania's land. The success of subsistence pastoralists in Northern Tanzania depends on rangelands' health. Understanding and monitoring rangeland conditions is an essential step to design management interventions which increase long term sustainable utilisation in times of climate change. The study area covers 300 km^2 in the Greater Kilimanjaro Ecosystem where livestock keepers co-exist with wild herbivores moving between Amboseli, Enduimet Community Wildlife Management Area and the Lake Natron ecosystem. A team composed of local government representatives, members of pastoralist communities and ecologists has tested a series of indicators which can be measured with relatively simple tools, and that can rapidly inform communities of the conditions and vulnerability of the pastures for rapid adaptation responses.

***Key words**: Rangeland, pastoralists, livestock keeping, climate change, ecosystem*

INTRODUCTION

Pastoralist communities depend entirely on the ecosystem services that rangelands provide. The transition between transhumant and semi settled lifestyles, the growth of pastoralists populations and relative livestock numbers and the conversion to cropland from both pastoralists and migrants from encroached high rainfall areas are key determinants of rangeland over-utilisation and consequent degradation. Moreover, erratic rainfall patterns don't allow communities to rely on traditional survival strategies and compromise the rangelands' capacity to recover from the extraordinary anthropological pressure. Rangeland ecological monitoring is a powerful tool to inform policy makers, conservationists and communities of critical degradation patterns to prioritise strategies for ecological recovery and mitigate severe depletion of local resources. The results of the ecological monitoring are part of the ECO-BOMA project, a EU-funded intervention aimed at improving and increasing the capacity of vulnerable

Maasai Pastoralists in Northern Tanzania to cope and adapt to the adverse effects of climate change as well as contributing to poverty reduction and ameliorating the livelihoods (EuropeAid Grant Contract CRIS DCI-ENV/2014/354-361). The project is implemented by Istituto Oikos in partnership with the Arusha and Meru District Councils, the Nelson Mandela African Institute of Science and Technology and Oikos East Africa.

METHODS

The study focuses on 350 Km^2 of Maasai Steppe stretching between the Western slopes of Mount Meru in the Arumeru District and the Eastern boundary of Enduimet Community Wildlife Management Area in Longido District (Figure 1), at an altitude varying between 1200 and 2000 m ASL. The area falls in the semi-arid belt of Sub-Saharan Africa (FAO, 1989) with annual precipitation in summer varying between 300-800 millimetres, 200-500 millimetres in winter. The area is dominated by dry rangelands and is composed by a mosaic of habitats. Approximately, one third of the area is covered by grasslands, woodland 50%, and subsistence farmland covers the remaining 20%. Even though crops and villages occupy only slightly more than 20% of the area, land conversion and natural resources exploitation is evident throughout (Figure 7). Woodlands are dominated by secondary acacia forests and thickets. Systems of hills are located in the central and lower portions of the study area, toward the slopes of Mount Meru, and reach an altitude ranging between 1500 and 2000m ASL. Although the study areas are scattered with human settlements, wildlife sightings are regularly reported, confirming the importance of this area as an ecological corridor in the Greater Kilimanjaro Ecosystem. Populations of large

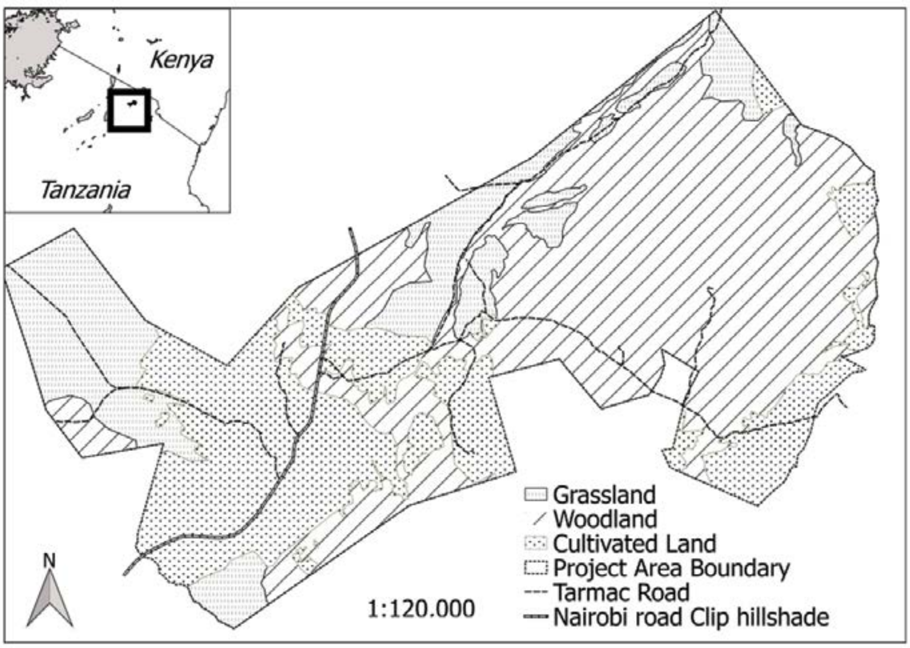

Figure 7. *Map of the study area with main land uses.*

herbivores typical of the grass plains such as Thomson's gazelle, Grant's gazelle, impala zebra, wildebeest, giraffe, eland, ostrich and elephant move seasonally according to availability of grass and water.

Rangeland Ecological Monitoring

Reed *et al*. (2008) state that if indicators are to influence land management, then they must be easy for local communities to use, in addition to providing accurate assessments of environmental sustainability. Several methods were tested to understand their practicability and to set up a sound community-led ecological monitoring program. In Table **8** we present the pool of indicators monitored covering livestock count, distribution and movement and the grass cover-landscape features.

The distance sampling method estimates the density and abundance of livestock and gives an indication of the grazing pressure. Distance sampling is a reliable method for the abundance and density estimation of animals and plants (Buckland et al., 1993). A total of 12 x 2 km long transect were located in three different villages: Lemanda, Mkuru and Engutukoit (Figure); transects were run mainly through grasslands and woodlands, avoiding farmlands.

Transects were walked on a monthly basis by a team composed of three people. Data were recorded as perpendicular distances to targets from the line actually walked, even if slight deviations had been made around trees or thorn bushes. Herds of animals were recorded as a single observation, with a reading taken to the apparent centre of the group and all species within the herd recorded on the same line. For moving targets, perpendicular distances were recorded to the first location where the group was seen. However, teams were instructed to maintain focus on the left and right to avoid 'guarding the line' and to ignore observations possibly along the line but further away than ~ 200m. Herds that moved into sight while the team was paused counting large groups were ignored.

Data were gathered in a buffer of 500 m to the left and right side of the transect line. With the use of a range finder, animals were counted and the distance between

Table 8. Selected indicators to assess rangeland conditions

Indicator	Method	Target
Livestock: count/distribution/ movement	Distance sampling method through ground foot transects	Cow, sheep and goat
Land cover-landscape features	Monitoring Rangeland Health Guide (2010)	Grass, bare ground, trees
Tree cutting and charcoal production	GPS point recording of the activity	Trees recently cut, presence of smoke and sacks of charcoal
Invasive plant species	Line transects	Alien and or invasive plants
Weather data	Weather stations	Temperatures, rainfall, wind
Market prices of basic commodities	Market survey	Livestock, oil, soap, sugar, etc..

each centre of the animals' group and the observer on the transect line is measured, furthermore; for each sighting the GPS position is recorded. In thicker vegetation, one team member would move to the location of the herd to act as a better rangefinder target, and to count the group more accurately. Distance data were analysed with the support of the *Distance 7.0* software. The livestock density data were normalised and expressed in Tropical Livestock Units (TLU) to be comparable with other studies.

Monitoring Rangeland Health relies on a method developed to monitor the long-term changes in rangeland health through a set of indicators suitable for a wide variety of arid and semi-arid landscapes, including areas that are being managed for livestock, wildlife, or both (Riginos & Herrick, 2010), the methodology applied follows Riginos & Herrick (2010) guidelines, some measurements were slightly adapted. The data presented focus on a pool of indicators which were both easy to collect and meaningful for the target communities.

Deforestation due to extractive practices for commercial charcoal sales has a profound impact on semi-arid savanna systems in Tanzania where vegetation regeneration is especially slow (Butz, 2013). To assess the pressure on the woodlands tree cutting and charcoal production points (Figure 3) were recorded for 12 months.
Market prices of basic commodities can help to assess economic stress in the target communities, in particular livestock sale values can inform on acute stress in the pastoral systems (prices lower than market values) or opportunities for destocking.

Alien and invasive plants can reduce the rangeland carrying capacity up to 90% (Witt et al., 2017); presence and distribution of a pool of 5 invasive plant species, specifically *Datura stramonium*, *Cylindropuntia exaltata*, *Opuntia stricta*, *Parthenium hysterophorus* and *Ipomea hildebrandtii* were recorded. The data were collected along the same transect lines used for the distance sampling. A rapid survey was also conducted in the dry season and will be repeated in the wet season. The survey did not return significant data on distribution and presence of annual species but helped to assess the presence of permanent invasive species such as *Cylindropuntia exaltata* and *Opuntia stricta*.

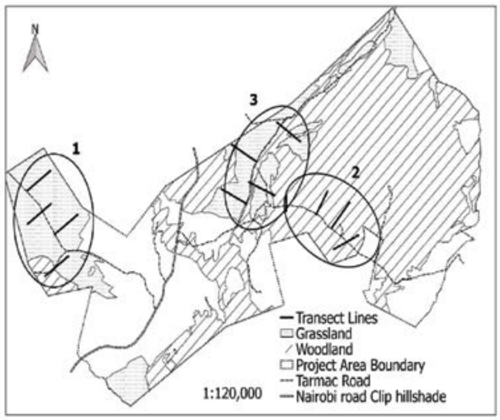

Figure 2. *Transect lines locations*

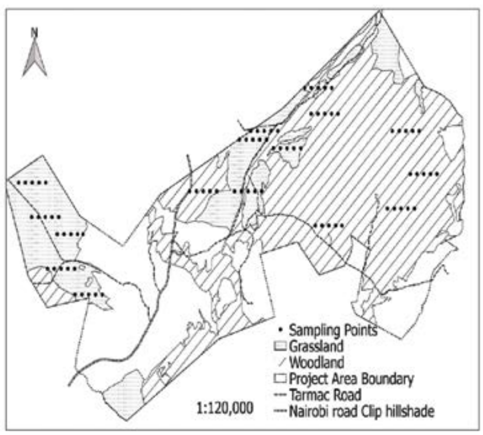

Figure 3. *Sample points locations for Monitoring Rangeland Health Guide Method*

Data are collected walking from the centre point (GPS point) toward each of the four cardinal directions. In each direction, the data are collected every 5m totalling 25 readings/ sample. Three different macro-classes of reading: vegetation cover, vegetation height and gap are measured (Table 9). Vegetation cover: this index measures the soil cover, perennial grasses and annual plants, which are disaggregated in the original methodology, were aggregated for the case study presented here because the intense grazing made it very problematic to identify grass species. Height: the second class of reading is the height of plants inside a 1 m^2 plot at the point where the measuring stick is laid down; six classes of height determine the structure of the steppe monitored. Gap reading is composed of the basal gap and canopy gap. The basal gap occurs when the distance between two living plants is above 1 m and so is greater than the total length of the measuring tool.

Table 9. Classes of Readings from the Monitoring Rangeland Health Guide

COVER	HEIGHT	GAP
Bare ground	<10 cm	Basal Gap
Shrub	10-50 cm	Canopy Gap
Tree	50-1 m	
Plant	1-3 m	
Herbaceous litter	2-3 m	
Woody litter	>3 m	
Rock		

RESULTS

Weather data delineate the meteorology and more long term, climate conditions of the area. Two weather stations were recently installed in Oldonyosambu and Mkuru villages and represent the only source of temperature data from the area. The data collected during the first 24 months of operation are charted in Fig.8.

Rainfall distribution is bimodal, although the distinction between the long rainy season, usually running from late January to May and the short rainy season, usually from later September to late November is not strongly apparent in these data. The annual variability of total rainfall is evident in the first two years of data collection, with a sharp drop of rainfall in 2017 (total annual rainfall = 300 mm). Preliminary results from 12 months of livestock across two seasons show changes in both livestock density and composition. a number of cattle are shown in figure 4 where and the percentage is the composition in species of the herds. The seasons subjected to analysis are respectively Season 1 from February to May corresponding to the green-wet season and Season 2 from June to September, the long dry season.

Figure 9 shows an estimated sustainable stocking rate of 0.3 TLU/Ha which is derived from average published sustainable stocking rates for comparable altitude, rainfall and ecological conditions in East Africa (Hein et al., 2008; Fynn et al., 2000; Mulindwa *et al*., 2009). This threshold is a conservative value but we felt it aids communities understanding the order of magnitude of livestock pressure on the rangelands. Season 1 (Feb-May) has higher density compared to season 2 (Jun-Sep) with the exception of Mkuru's station where a higher density in the June-Sep season was recorded. This unusual pattern could be attributed to the presence of a belt of livestock-encroached crops which intersects one of the transects, harvested fields are opened to the livestock which fees on the left-over stubble.

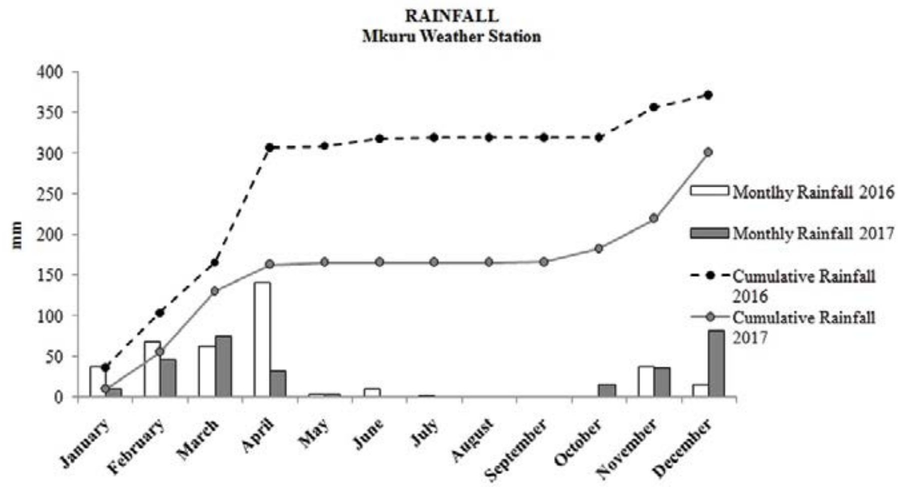

Figure 8. *Cumulative and monthly rainfall data from Mkuru Village, 2016 and 2017.*

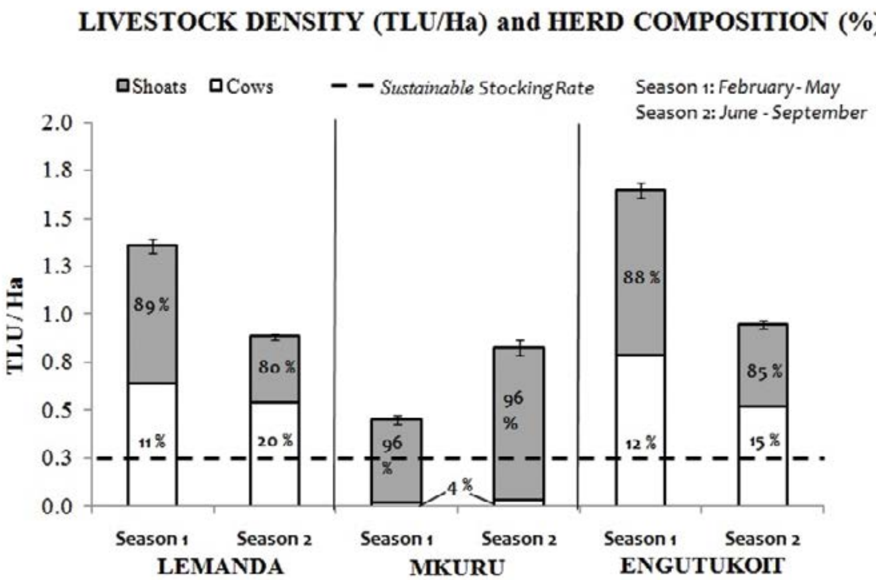

Figure 9*. Livestock Density expressed in TLU/Ha and herd composition*

It is evident that the herds composition is dominated by small ruminants, sheep and goats, which reach 90% of the total livestock numbers and are likely to be more resilient to the rainfall conditions and grass cover (Figure 9).

The percentage of bare ground found is considerable, representing almost two thirds of the sample and equally high in both the habitats studied (approx. 65-66%). The plant cover is consequently remarkably low: 18% across the grasslands and 6% in the woodland. Bare ground information matched with basal gap presence provides a valuable information of the gravity of the lack of ground cover; grassland and woodland show similar levels of bare ground prevalence, respectively 65% in grasslands and 66% in woodlands, the average basal gap in the woodland is as high as 92% suggesting an even higher concentration of grazing in areas where trees are still present (Table 10).

Five invasive plant species presence and distribution was assessed and monitored: *Datura stramonium, Cylindropuntia exaltata, Opuntia stricta Parthenium hysterophorus* and *Ipomea hildebrandtii*. The preliminary results show very high concentration of *Cylindropuntia exaltata* along some roads and fences. The other species presence did not indicate an imminent risk, although further efforts are needed to inform communities of risks and management practices of invasive plants.

DISCUSSION

Rangelands outside protected areas are common pool resources, or communal lands, and their utilisation is regulated by customary rights (Nelson *et al*., 2010). Users of common lands tend to maximise the benefits from utilisation which can lead to overexploitation of resources (Ogutu *et al*., 2016). A high prevalence of bare ground is ubiquitous and highly prevalent in all sampled areas; this finding confirms the results of Critchlow *et al*. (2017) technical report on rangeland vegetation in the Tarangire-Manyara ecosystem. High prevalence of bare ground, combined with the average height of the herbaceous vegetation, suggest a high level of stress of the rangelands which has led to an evident shortfall of pastures. Adding to this scenario a highly variable rainfall with an increasing number of dry months and high

Table 10. Selected categories of vegetation cover and measured prevalence

Average %	Grassland	Woodland	Percentage range of variation	
			Min	Max
Bare Ground	65	66	53	76
Tree	1	14	0	3
Plant	18	6	11	26
Basal Gap	44	92	1	68

numbers of livestock heads indicates that the rangeland is overexploited. The long term work on rangeland ecology of Western et al. (2015) shows that when the causes of extreme shortfalls are due in large part to factors such as stocking rates and herding practices, then the causes of shortfalls can be predicted and manageable. This provides a sound argument for advocating for the urgent adoption of more sustainable livestock keeping practices.

ACKNOWLEDGEMENTS

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THERMO TOLERANCE OF AN INACTIVATED RABIES VACCINE FOR DOGS

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ABSTRACT

This study provides the first robust data that the antibody response of dogs vaccinated with Nobivac® Rabies vaccine stored for several months at high temperatures (up to 30 °C) is not inferior to that of dogs vaccinated with vaccine stored under recommended cold-chain conditions (2 - 8 °C). A controlled and randomized non-inferiority study was carried out comparing the four-week post vaccination serological responses of Tanzanian village dogs inoculated with vaccine which had been stored at elevated temperatures for different periods of time with those of dogs vaccinated with the same product stored according to label recommendations. Specifically, the neutralizing antibody response following the use of vaccine which had been stored for up to six months at 25 ºC or for three months at 30 ºC was not inferior to that following the use of cold-chain stored vaccine. These findings provide reassurance that the vaccine is likely to remain efficacious even if exposed to temperatures for limited periods of time and, under these circumstances, it can safely be used and not necessarily destroyed or discarded. The availability of thermotolerant vaccines has been an important factor in the success of several disease control and elimination programs and could greatly increase the capacity of rabies vaccination campaigns to access hard to reach communities in Africa and Asia. We have not confirmed a 3-year duration of immunity for the high temperature stored vaccine, however because annual re-vaccination is usually practiced for dogs presented for vaccination during campaigns in Africa and Asia this should not be a cause for concern. These findings will provide confidence that, for rabies control and elimination programs using this vaccine in low-income settings, more flexible delivery models could be explored, including those that involve limited periods of transportation and storage at temperatures higher than that currently recommended.

***Key words**: Canine-mediated human rabies, cold-chain, Tanzania, thermotolerance, vaccine potency*

INTRODUCTION

Canine mediated human rabies is a neglected tropical zoonotic disease (WHO, 2005) responsible for an estimated 59,000 deaths and 8.6 billion USD in economic losses annually (Hampson *et al.,* 2015). The area with the highest incidence (3.6 / 100,000) is thought to be rural Africa (Knobel *et al.,* 2005; Hampson *et al.,* 2015). This toll is made more tragic by the fact that highly effective vaccines, when used to protect domestic dogs in endemic countries, are able to eliminate the disease at source and, when used as post-exposure prophylaxis (PEP), can protect humans following bites from rabid animals (Lankester *et al.,* 2014).

Where annual canine vaccination is implemented, modeling and empirical data suggests that a coverage of 70% of the domestic dog population during annual vaccination campaigns will be sufficient to control and eliminate canine rabies (Coleman & Dye, 1996; Hampson *et al.,* 2009). While reaching this target has been shown to be feasible in most demographic settings in Africa and Asia (Davlin & Vonville, 2012), challenges still remain. Even small gaps in vaccination coverage can significantly delay time to elimination (Townsend *et al.,* 2013). Therefore, where vaccination strategies rely on delivery through annual campaigns, a low turnout in only a few communities (that can arise, for example, through ineffective advertising or poor timing (Minyoo *et al.,* 2015) can jeopardise the success of the wider programme.

Despite their effectiveness, team-led mass dog rabies vaccination campaigns are expensive to implement, with high fixed costs, often associated with personnel and vehicle use, resulting in costs ranging from \$1.18 to \$6.36 for each dog vaccinated (Minyoo *et al.,* 2015; Taylor & Nel, 2015). Furthermore, due to the requirement of storing vaccines according to label recommended 'cold-chain' conditions (2 - 8 °C), the reach of the campaigns is limited to areas within easy reach of facilities that can store veterinary vaccines under stable and reliable refrigeration. Consequently developments that increase the flexibility with which vaccines can be delivered to and stored in communities may result in improved coverage and are likely to reduce the rate at which the inter-campaign coverage declines.

The cold-chain was originally devised as a set of guidelines that could be implemented worldwide to ensure that vaccines distributed through the World Health Organisation's Expanded Programme on Immunization (Keja *et al.,* 1988) were handled and stored in consistent conditions (Milstien *et al.,* 2006). The approach was relatively simple: keep all vaccines within the temperature range 2 – 8 °C. However, what started as a means of protecting the potency of vaccines during distribution slowly led to the emergence of a dogmatic view of how vaccines should be stored. As a result the planning of campaigns rarely considers the thermotolerance of specific vaccines, which limits strategic options and the flexibility with which vaccines are handled in the field (Milstien *et al.,* 2006). Moreover, immunization programs typically require significant investment in infrastructure and management, including widely distributed refrigeration units for storage and cooler units for transportation. In many parts of the world, where electricity provision is poor, refrigeration units powered by kerosene, gas or solar power may be expensive, unreliable, or not available, constraining the use of vaccines in remote communities and limiting how vaccination strategies can be designed (Zipursky *et al.,* 2014).

The development of thermotolerant vaccines that can be stored at ambient temperatures for extended periods of time could alleviate some of these constraints. In addition, with studies estimating up to 18% of total vaccination costs can be eliminated by the use of thermostable vaccines (Karp *et al.,* 2015), their deployment may result in considerable economic savings. Successful examples of thermotolerant formulations being used to deliver vaccines in hard-to-reach communities in Africa and Asia include meningitis A (Zipursky *et al.,* 2014) and hepatitis B vaccines for children (Hipgrave, Maynard, et al. 2006; Wang et al. 2007; Otto *et al.,* 1999; Sutanto et al. 1999; Hipgrave, Tran, et al. 2006), and Newcastle disease vaccines for chickens (Mgomezulu *et al.,* 2009). Moreover, the development of thermotolerant formulations, that enabled novel storage solutions to be developed and that, critically, empowered local communities to deliver their own campaigns, played a pivotal role in the eradication of small pox and rinderpest (Henderson & Klepac, 2013; Mariner *et al.,* 2012). A thermotolerant rabies vaccine could have the same transformative effect for the planned elimination of canine-mediated human rabies.

The aim of this study, therefore, was to investigate the thermotolerance of the Nobivac® Rabies vaccine, commonly used in mass dog rabies vaccination campaigns around the world. Our principle objective was to determine whether the immunological response elicited by doses stored under non-cold-chain conditions was not inferior to the response elicited by doses of the same vaccine stored under normal cold-chain conditions.

METHODS

To achieve this objective a controlled and randomized non-inferiority trial was carried out. The study compared the serological response at four weeks post vaccination in Tanzanian village dogs inoculated with a vaccine (Nobivac® Rabies, MSD Animal Health, Boxmeer, The Netherlands) which had been stored at elevated temperatures for different periods of time, with the response in similar dogs vaccinated with the same product stored according to label recommendations (at 2 - 8 °C).

Sample size calculations

The trial comprised seven groups of dogs each receiving Nobivac® Rabies vaccine stored under group specific conditions (described below). From a previous study, which involved western European pet dogs (MSD Animal Health, 2009), relatively comparable to the Tanzanian pet dogs used in this study, forty 21-day post-vaccination titres were compiled. The geometric mean of the titres, which appeared log-normally distributed, was 3.7 IU / ml (1.89 log_2; SD of 2.02 log_2). Based on this, sample size calculations estimated that 40 dogs per group would give a power of more than 80% to establish non-inferiority to a margin of -1.2 log_2. This test (based on the lower limit of the one-sided 95% confidence interval) is equivalent to requiring for each comparison that the difference between log titres of the elevated storage group and the cold-chain reference will be > -1.2 log_2. Titre values occurring at this limit will be approximately 1.89 (the 'normal' level of historical data) minus 1.2 log_2. This value equals 0.69 log_2 (or 1.6 IU / ml), still well above the defined minimum protective level of 0.5 IU / ml (World Health Organisation, 1992). With an assumed loss-to-follow-up of approximately 20%, the number of dogs recruited into the first phase of the study (day-zero) was increased to 50 per group (total dogs = 350). In summary the trial was powered to detect a difference of more than 1.2 log_2 titre units between dogs receiving Nobivac® Rabies vaccine stored under cold-chain conditions and those receiving vaccine stored outside of the cold-chain.

Preparation of stored vaccines

The vaccine storage conditions for each of the seven groups were as follows:

1. Vaccine stored at 2 - 8 °C (normal cold-chain conditions)
2. Vaccine stored at 25 °C for three months (90 days)
3. Vaccine stored at 25 °C for six months (180 days)
4. Vaccine stored at 30 °C for three months
5. Vaccine stored at 30 °C for six months
6. Vaccine stored at 37 °C for three months
7. Vaccine stored at 37 °C for six months

Warehouse storage at 2 – 8 °C was used before and after all incubation steps and as the storage for group 1 vaccines. For the 90 and 180 day incubation at elevated temperatures a Hielkema room was used for storage at 25 °C (± 3 °C) and 30 °C (± 3 °C), whilst a Binder CB150 incubator was used for storage at 37 °C (± 2 °C). Sequential numbers from 1 to 392 were then each randomly assigned to one of the seven groups and, following storage, all of the 1ml vials of vaccine within each group were labeled with one of the numbers that had been assigned to that particular group. In this manner the sequential numbers were randomly distributed among the groups.

Study location and enrollment of dogs – Day-zero

To ensure that most of the dogs recruited into the study were seronegative for rabies the trial focused on villages that had not previously been targeted by mass dog rabies vaccination campaigns and are not served by private veterinary services. These target villages, located within the district of Babati (north-western Tanzania, GPS -4.32 (lat), 35.60 (long)), were Duru, Endagwe, Gesbit, Hoshan and Yarotonik. To locate and recruit dogs for the study, two field teams travelled on foot from household to household enquiring at each house whether dogs were owned and, if so, requesting participation in the study. Owners were asked whether any dogs had previously received rabies vaccination with only unvaccinated dogs being selected. Following the signing of an informed consent form by the head of the household, all available dogs were given a full clinical examination. In order to control for age and body condition only adult dogs (estimated to be between six months and five years of age) with a body condition score between two and four inclusive (1 = thin; 5

= fat) were selected (Evans, 2010). Following examination, each dog was permanently marked with a microchip (HomeAgain®, Merck Animal Health), assigned a sequential number and inoculated subcutaneously in the scruff of the neck with 1 ml of Nobivac® Rabies vaccine from the vial with the same number. Dogs presented for vaccination by the owners, but that did not fulfill inclusion criteria, were immunized with standard cold-chain stored vaccine but were not enrolled in the study. To ensure that participating dogs were seronegative at the time of a trial, a blood sample was collected prior to vaccination and stored for post-hoc serological analysis. Only dogs with a pre-vaccination titre of < 0.5 IU / ml were included in the analyses.

All dog owners were given a contact telephone number to call if, following immunization, any adverse effects were seen that were possibly attributable to the inoculation. Owners were also informed that dogs could not be considered to have been properly vaccinated and protected against rabies until after the 4-week follow up when all study dogs would be vaccinated with a dose of cold-chain stored Nobivac® Rabies vaccine.

Follow up visit: Day-28

Twenty-eight days later the field teams returned to the same households and, following identification using a microchip scanner, each participating dog was given a clinical examination and a blood sample was collected. During this visit, a 1 ml dose of cold-chain stored Nobivac® Rabies vaccine was inoculated.

Sample processing

All blood samples collected on day zero and day-28 were centrifuged and serum extracted the following day. Sera were stored at minus 20 °C prior to being shipped to the rabies reference laboratory ANSES (France) where serological analyses took place.

Serological analyses

As one of the methods recommended by the OIE Terrestrial Manual, the Fluorescent Antibody Virus Neutralisation (FAVN) test (Cliquet *et al.,* 1998) was used for detection of antibodies against rabies virus. In brief, each serum sample as well as the positive and negative controls were distributed in four consecutive wells and serially diluted. The challenge rabies virus (CVS-11) containing approximately 100 TCID50/50µl (TCID50 = 50% tissue culture infective dose) was added to each well. After 60 minutes incubation, a volume of 50 µl of 4 $x10^5$ BHK21cells / ml suspension was added to each well and the micro-titre plates were incubated, in a humidified incubator with 5 % CO_2, for 48 hours at 36°C +/- 2°C. After incubation, the plates were stained by adding 50 µl of an appropriate dilution of a fluorescein isothiocyanate (FITC) anti-rabies monoclonal globulin to each well. A qualitative reading was performed according to specific positive fluorescent signal. The Spearman Kärber formula was used to calculate the $LogD_{50}$ titres of sera. The titres were expressed in International Unit per milliliter (IU / ml) by comparison of results obtained with those of the positive standard. The sera were tested over eight dilutions which allowed the quantification of titres ranging from 0.04 IU / ml (logD50= 0.24) to 218.26 IU / ml (logD50=3.95).

Assessment of a low-tech cooling system

To estimate the temperatures that non-cold-chain stored vaccines are likely to be exposed to during campaigns, and to assess the effectiveness of a low-tech cooling system, five digital temperature loggers (Sensormetrix, www.sensormetrix.co.uk) (loggers 1 - 5) were placed in a variety of locations in northern-western Tanzania and were programmed to record the temperature at midday for 31 consecutive days during the hottest period of the year (Feb – March). To replicate a low-tech method that might be used to keep vaccines cool when power and refrigerators are not available, loggers 1 and 2 were placed inside vehicles inside insulated vaccine storage boxes with bottles of water placed around them. The water inside the bottles was replaced every day using local tap water. Logger 3 was placed in a similar vaccine storage box inside a vehicle without water bottles. All of the vehicles were being used on rabies vaccination campaign duties in villages on the perimeter of the Serengeti - Maasai Mara ecosystem. Loggers 4 and 5 were placed inside cupboards in buildings in the Serengeti - Maasai Mara ecosystem. The data were downloaded using the software provided and the midday temperature recorded by each logger for each day of the study period was plotted.

Statistical analysis

In accordance with the WHO recommendations (World Health Organisation, 1992) 0.5 IU per ml of rabies antibodies is the minimum measurable antibody titre considered to represent a level of immunity in humans that correlates with the ability to protect against rabies infection. The same measure is used in dogs and cats to confirm a satisfactory response to vaccination. As neutralizing antibodies are considered a key component of the adaptive immune response against rabies virus (Hooper *et al.,* 1998) antibody titres measured at around 28 days after inoculation are often used as an indicator of the potency of rabies vaccination (Kennedy *et al.,* 2007; Aubert, 1992). Titre measurements were statistically analyzed using ANOVA. Post-hoc estimates of the differences between the elevated storage conditions and the cold-chain stored vaccine were calculated with one-sided 95% confidence intervals. The null hypothesis, of a storage condition being inferior to the cold-chain storage, was being tested for each of the elevated conditions in a hierarchical testing procedure: any given storage condition was only tested if storage conditions at lower temperatures (but same duration), and for shorter duration (but at the same temperature), had been found statistically non-inferior to the cold-chain storage condition (i.e. the null hypothesis of being inferior had been rejected). This hierarchical testing procedure is comparable to certain dose finding studies with ordered hypotheses with increasing doses (Edwards & Madsen, 2007) and does not need alpha-level adjustment.

An additional exploratory analysis, examining whether storage conditions impact seroconversion (≥ 0.5 IU / ml), was performed using a logistic regression model with group and seroconversion as the explanatory and dependent variables respectively. Finally, an analysis was performed, according to international regulatory criteria (Pharmacopoia 2013), to determine whether vaccination within each group was satisfactory. For a group to be determined satisfactory the group arithmetic mean titre following immunization must be ≥ 0.5 IU / ml and less than 10% of the animals immunized must have a titre lower than 0.1 IU / ml (Pharmacopoia, 2013). All statistical analyses were performed using R-statistical environment (Team, 2013) .

RESULTS

Safety / clinical issues

Following inoculation there were no adverse events reported by the dog owners during the 28 day period after vaccination. However, during the day-28 follow up visit, two dogs were reported to have died of unknown causes with non-specific signs. Although the dates of these deaths were not recorded, the owners stated that they had occurred closer to the day-28 visit than the day-zero inoculation. We conclude therefore that these deaths were not related to vaccination and, further, that any adverse events that might have been experienced by dogs in any of the groups were of a mild nature such that the vaccines within each group can be considered safe.

Lost to follow up and post-inclusion removal

Because more households were visited per day than was expected and despite sample size calculations indicating that 350 dogs were required a total of 392 dogs were actually enrolled into the study and received a day-zero inoculation. At the day-28 visit, 339 of these dogs were available for follow up and were successfully re-sampled, 49 were lost to follow-up, and four were excluded due to operator failure (failed inoculation, sample volume was too small or the sample was misplaced). Five out of the 392 dogs (1.3%) sampled at day-zero were subsequently found to have pre-vaccination rabies titres ≥ 0.5 IU / ml. Two of these five dogs were lost to follow up whilst three were included in the 339 dogs re-sampled at day-28. Because these three tested seropositive at day-zero they were subsequently excluded. As a result a total of 336 dogs were included in the analyses with between 46 and 52 dogs per group.

Analyses

Day-28 antibody titre comparison

The primary outcome variable for this study was the day-28 post-vaccination antibody titre. The group geometric means, plus the mean and standard deviation of the log transformed titre data are shown in Table 1. The output of the ANOVA analysis, examining the explanatory effect of group on the log of titre, is presented in Table 2, whilst Figure 1 presents a simple graphical summary. Although a downward tendency can be seen in the level of antibody production, the results indicate that groups 2 – 4 were not inferior to group 1 according to the pre-set criteria (i.e. the difference between the groups did not exceed 1.2 $\log_2$ titre units). Therefore for groups 2 – 4, titres stimulated by Nobivac® Rabies vaccine stored under elevated storage conditions are not more than 1.2 $\log_2$ titre units below titres stimulated by cold-chain stored vaccine. For groups 5 – 7, titres were not more than 1.2 $\log_2$ titre units below those titres stimulated by cold-chain stored vaccine but the confidence intervals did not sufficiently exclude this possibility. For this reason we were unable to conclude that groups 5-7 were equivalent to the cold-chain stored vaccine group.

Table 1: Group summary data - the number of dogs in each group and the day-28 log mean, standard deviation, and geometric mean values are shown; Day-28 log2 mean and Day-28 SD represent the average and standard deviation of the log (base 2) transformed data for each group

Group	Number of dogs	Day-28 log_2 mean	Day-28 SD	Day-28 Geometric mean (IU / ml)
1	50	0.8	1.9	1.8
2	46	0.9	1.7	1.8
3	52	0.6	1.5	1.6
4	46	0.2	1.4	1.2
5	47	-0.1	1.8	1.0
6	48	-0.1	1.8	0.9
7	47	0.0	2.1	1.0

Table 2: Estimates and one-sided confidence intervals for the difference of titre levels between the elevated-temperature stored vaccine groups and the cold-chain stored vaccine group as derived from ANOVA results

	Estimate	Standard Error	Lower 95% confidence limit (one-sided)
Group 2 v 1	0.05	0.35	-0.54
Group 3 v 1	-0.18	0.35	-0.75
Group 4 v 1	-0.60	0.36	-1.19
Group 5 v 1	-0.88	0.35	-1.46
Group 6 v 1	-0.96	0.35	-1.54
Group 7 v 1	-0.80	0.35	-1.39

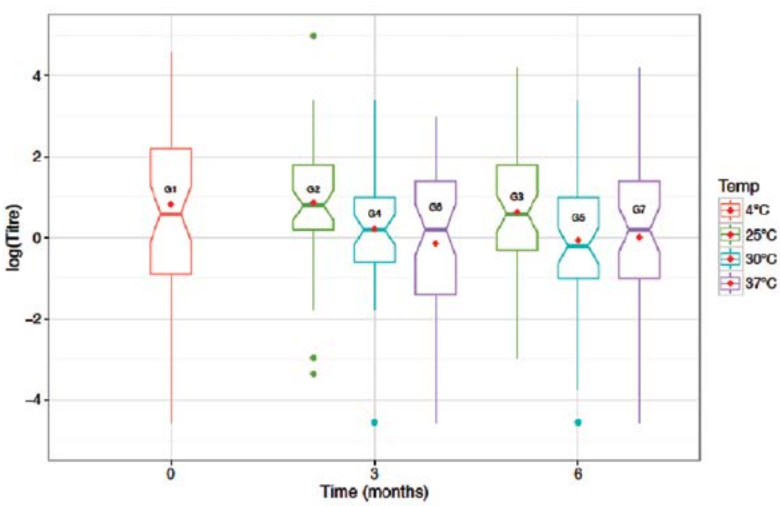

Figure 1: *A boxplot showing the range of (2log) day-28 titres produced by vaccine stored at elevated temperatures for zero (cold-chain), three or six months (red diamond = 2log titre mean; G1 – 7 = groups 1 - 7).*

Exploratory analysis: Seroconversion at day-28

An additional exploratory analysis was performed to examine whether storage conditions impact seroconversion. Figure 2 summarizes the observed percentages of dogs that seroconverted. The results of the logistic regression model (Supplementary File 1) suggest that, when compared to group 1, the proportion of dogs that seroconverted was significantly lower for groups 5 – 7 ($p < 0.05$), whilst for groups 2 - 4 we were unable to demonstrate any significant effect of storage conditions on seroconversion ($p > 0.40$). As this analysis had not been specified in the design phase of the study we consider it exploratory and conclusions are not based upon the results.

Vaccine assessment

According to international regulatory criteria, a rabies vaccine can be considered satisfactory if, following immunization, the group arithmetic mean titre is ≥ 0.5 IU / ml and less than 10% of the animals immunized have a titre lower than 0.1 IU / ml (Pharmacopoia, 2013). Applying this definition (using summary data shown in Supplementary file 2), all seven groups had arithmetic mean titres > 0.5 IU / ml and only group 7 had more than 10% of dogs with a titre < 0.1 IU / ml. Under this definition the vaccines from groups 1 – 6 can be considered satisfactory at day-28 post-vaccination.

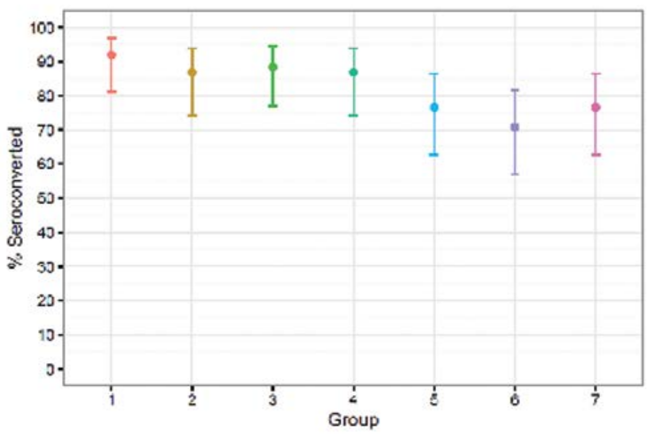

***Figure 2:** The percentage of dogs within each group that seroconverted (≥ 0.5 IU / ml) is shown. Whiskers represent the 95% confidence intervals, calculated using the Wilson method (Wilson 1927).*

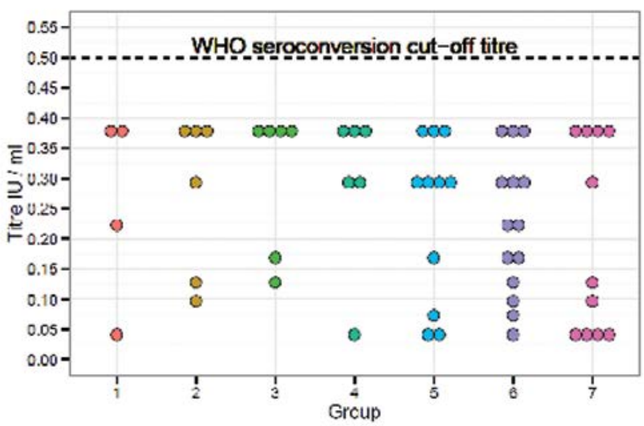

***Figure 3**: A dot-plot showing the titres (IU / ml) of all the dogs in each group that did not seroconvert (dashed line indicates the minimum seroconversion titre (World Health Organisation 1992).*

Assessment of a low-tech cooling system

The temperature logger data presented in Figure 4 shows the range, and the number of days (count), of each midday temperature recorded by the five loggers. For loggers 1 - 5 the maximum midday temperature (and the number of midday temperatures that exceeded 30.0°C) were, respectively, 29.6°C (0), 28.4°C (0), 36.7°C (5), 35.7°C (7) and 35.3 (15).

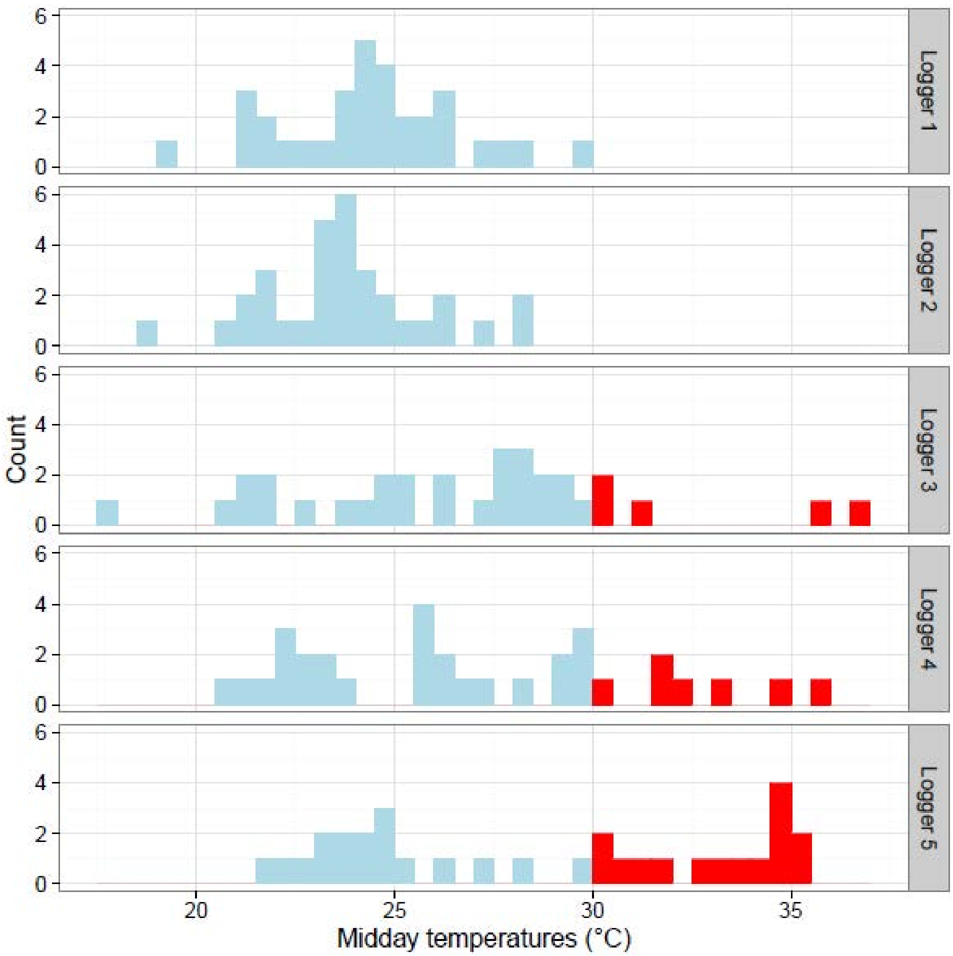

Figure 4: *A series of histograms showing the range of midday temperatures and the number of days (count) that each temperature was recorded by the five loggers (loggers 1 – 5). Temperatures < 30°C are coloured blue, whilst temperatures ≥ 30°C are red.*

DISCUSSION

This non-inferiority study has provided the first robust data that the neutralizing antibody response in dogs vaccinated with Nobivac® Rabies vaccine stored for several months at temperatures far in excess of recommended cold-chain conditions is not inferior to that of dogs vaccinated with the same vaccine stored under cold-chain conditions. Specifically the effectiveness of the vaccine at stimulating rabies antibody was not inferior to cold-chain stored vaccine when, following cold-chain storage, it was stored for up to six months at 25 ºC (groups 2 and 3) or for three months at 30 ºC (group 4). These findings were supported by the exploratory analysis, which suggested that the proportion of dogs that seroconverted was not significantly affected when the vaccines were stored at these same elevated temperature conditions. As the neutralizing antibody response against rabies is considered a surrogate of protection (Aubert, 1992), we consider that this vaccine, exposed to this range of temperatures, is likely to remain efficacious.

Although groups 2 – 4 were not found to be inferior to cold-chain stored vaccine, there was a downward tendency in the titre levels produced by vaccines stored under elevated storage conditions (Figure 1). This tendency indicates that storage outside of the cold-chain does, as expected, impact antibody response. However the downward tendency was slight, and when applying the criteria for assessing whether a vaccine is satisfactory were used (Pharmacopoia, 2013), vaccines stored at 30 ºC for six months (group 5) and 37 ºC for three months (group 6) would both be considered satisfactory. Even group 7 dogs, immunized with vaccine stored at the most extreme conditions (37 ºC for six months), had an arithmetic mean titre of 2.3, considerably higher than the accepted minimum required antibody titre of 0.5 IU / ml (World Health Organisation, 1992).

Although we did not generate data on duration of immunity, titre following primary immunization has, for other viral infections, been shown to be a robust predictor of induction of central B cell memory and thus the response upon booster immunization (Zanetti *et al.,* 2005). As such it is possible that for dogs in groups 2 - 4 duration of immunity would not be significantly shorter than those vaccinated with cold-chain vaccine. Moreover, dogs in canine rabies-endemic countries are typically vaccinated during annual campaigns, irrespective of prior vaccination status, resulting in many dogs being re-vaccinated every year. Given that the label use of these vaccines recommends a booster to be given only after every three years, this increased frequency of dosing would further boost titres (Duval *et al.,* 2005). We therefore consider it unlikely that the duration of immunity of dogs immunized with vaccines stored under the conditions of groups 2 – 4 will be a cause for concern. Additionally, many of the 58 dogs classified as seronegative had a day-28 titre between 0.1 and the cut off of 0.5 IU / ml (Figure 3). Some of these dogs may also have sufficient memory to be protected upon challenge and to respond with protective titres upon boosting.

The promising results from this trial raise several additional questions pertaining to the thermotolerance of Nobivac® Rabies vaccine: for example, the vaccine was stored under elevated temperature conditions for up to six months prior to use and it would be interesting to know for how much longer this vaccine could be stored whilst retaining equivalent anti-virus antibody response. Furthermore, the raised temperature conditions that the trial vaccine was exposed to during the preparation phase were constant and it would be interesting to examine whether fluctuating temperature conditions impacts anti-virus antibody response.

What are the implications of this trial? Thermotolerance was pivotal in the eradication of small pox and rinderpest as it allowed emphasis to be placed on community involvement in both eradication campaigns (Henderson & Klepac, 2013; Mariner *et al.,* 2012). Furthermore, it has been shown to increase the effectiveness of the delivery of a number of human and animal vaccines (Levin et al. 2007; Mgomezulu *et al.,* 2009). Thermotolerance could bring similar benefits to the control of canine-mediated human rabies. Specifically the availability of a thermotolerant vaccine could allow novel and cost-effective delivery models for mass dog rabies vaccination to be developed. For example, the results will give reassurance that this vaccine might be used effectively following a period of non-cold-chain storage in remote communities where access to power and cold-chain storage facilities are scarce. Further, thermotolerant vaccine could be carefully stored in remote communities for extended periods allowing dogs to be vaccinated at various times throughout the year, rather than annually when mass dog vaccination campaigns pass through. In this way puppies, born after a central-point vaccination campaign, and new dogs brought into the area, could be vaccinated in a timely manner, reducing the rate at which the inter-campaign coverage level decreases. This will be especially useful in communities where the 70% target has not been reached. Thermotolerant vaccine stored in remote areas will also provide a lifesaving resource, for example in the emergency situation of an outbreak of rabies where rapid vaccination of the dog population is required to control the epidemic.

To explore the feasibility of transporting and / or storing vaccines for extended periods in remote areas where power is not available we compared the midday temperatures recorded in shady parts of buildings and within insulated vaccine storage boxes placed inside vehicles with temperatures recorded in similar boxes in which plastic water bottles, refilled daily with tap water, were placed ('low-tech' cooling system). The results suggested that the temperature inside the low-tech cooling system could be kept cooler than the ambient temperature of a building or a vehicle. Moreover, despite a maximum temperature during the study period of 36.7 °C, the temperature inside the low-tech cooling systems did not exceed 30 °C. As the tested rabies vaccine was thermotolerant when stored for three months at this temperature, this result was encouraging. This was an exploratory analysis and we only investigated one low-tech system. Further work is required to confirm whether low-tech systems are able to keep the temperature significantly lower than the ambient temperature and to explore other, potentially more effective systems, which could be made available to vaccinators working in remote areas to keep vaccines cool over extended periods of time.

In summary, this trial has shown that Nobivac® Rabies vaccine stored at elevated temperatures for extended periods of time retains its ability to stimulate a neutralizing antibody response. These preliminary findings are not an indication that the label recommendations for the storage of this vaccine should be ignored, however they will give confidence, to programs working with this vaccine to control rabies, that more flexible delivery models can be investigated, potentially involving the storage of this vaccine outside of the cold-chain for limited periods of time. These findings will contribute to the recent groundswell of momentum amongst international human and animal health agencies (Lankester *et al.,* 2014; OIE & WHO, 2015) that global elimination of canine-mediated human rabies is a logistically feasible, cost-effective and socially equitable goal.

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Conflicts of interest

Lankester, Czupryna, Palmer, Mzimbiri and Cleaveland have no conflicts of interest.
MSD Animal Health employs Wouters, Francis, Sutton and Sonnemans.

Research and ethical clearance

The research was carried out with the approval of the Institutional Animal Care and Use Committee, Washington State University (approval no. 04577 – 001), the Tanzanian Wildlife Research Institute (TAWIRI), the Commission for Science and Technology (COSTECH, Tanzania) and the Tanzania Food and Drug Administration (permit nos. 2011-213-ER-2005-141 and 2012-318-ER-2005-141).

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POOR WATER QUALITY A HEALTH RISK FROM WATER-BORNE DISEASES TO COMMUNITIES IN THE SERENGETI ECOSYSTEM, TANZANIA

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ABSTRACT

Evolutionary, water is the origin of life and provides indispensable ecosystem services required to support the life of people, livestock, diverse plant and wildlife species. In the Serengeti ecosystem, the quality of water from different sources remain to be investigated, and can be a major source of water-borne infections with adverse risk for local communities. Water quality is measured by direct physical appearance, determination of chemicals, ecological and microbiological contents, and dissolved oxygen and nutrients. Among many other sources of contamination, presence of faeces in water is a sign that such water is not suitable for human drinking without treatment. A study was conducted to establish the level of fecal contamination using qualitative field test kit. Out of 94 tested samples, 75 (79.8%) had faecal contamination, and 61 out of 75 (81.3%) cultured samples had bacterial growth. Basing on colony morphology and limited biochemical tests 28 water sources (45.9%) had bacteria that can cause enteric diseases to people including Escherichia coli, Proteus and Citrobacter species. However, molecular DNA-sequence analysis is important to establish the species and strains of the bacteria to establish their pathogenicity, and will be conducted soon. Awareness creation is important to minimize the incidences of diarrhea/dysentery in local communities in the Serengeti ecosystem.

INTRODUCTION

Many ecosystems in Tanzania encompass diversity of habitats including open grassland, wooded grassland, riverine forests, highland forests and wetlands, and provide diversity of niches for a variety and diversity of organisms (PATH, 2013). For generations the wetlands have provided life support to plants, animals and local communities (De Troyer *et al*., 2016). Evolutionary, water is the origin of life, therefore, water isone of the important and indispensable ecosystem services required by millions of people, livestock and a diverse of plants and wildlife species (De Troyer *et al*. 2016). However, the desired quality and quantity vary from one species to the other, and the environment often influences the intake (Stommel *et al*., 2016). In this regard, sustainable water resource management is important for biodiversity conservation and enhanced livelihoods in communities (GLOWS, 2007; Kvarnstrom *et al*. 2011). Increase in human population concurrent with expanding anthropogenic activities exerts ever-increasing pressure on water availability and quality and affects the wellbeing of animals and people (GLOWS, 2007; Stommel *et al*., 2016). Generally, about 60-70% of households in rural communities of Tanzania drink untreated water, predisposing them to high risk of contracting water borne diseases (PATH, 2013).

The Serengeti ecosystem is semi-arid with few seasonal rivers and streams flowing from Loliondo highlands in the eastern part of the ecosystem (Lyamuya *et al*., 2016). Therefore, water sources for people, livestock and wildlife in the ecosystem is either running water in seasonal rivers or shallow wells excavated in gorges or valleys near human settlements. Given the existing taboo in many agro-pastoral and pastoral communities of not using toilets or not sharing toilets among family members, it is obvious that the level of fecal contamination is likely to be high (WHO and UNICEF, 2012). Nomadic pastoralists on the other hand do not have time to construct toilets because of limited time spend in one area while grazing livestock. Inadequate use of toilets by communities exacerbates faecal contamination of both running water in streams or shallow wells from rainfall runoff during the rain season (PATH, 2013). Therefore, faeces from animals and people are likely to contaminate most of the stagnant water in swamps and shallow wells. Lack of potable water for human use is a predisposing factor for high incidences of diarrhea/dysentery in communities especially in pastoral communities in eastern Serengeti (GLOWS, 2007). Routine water quality monitoring in the ecosystem is conducted only on Mara River Basin from the source on the Mau Escarpment to its outlet at lake Victoria (GLOWS, 2007). Therefore, many of the water sources in the ecosystem are not monitored and the status of faecal contamination is not well understood. In 2012, a cross-sectional study was conducted using questionnaire survey to establish the common diseases in human and livestock. The findings showed that among other human diseases, about10% of community members in the ecosystem had succumbed to diarrhea/dysentery in the past one year (Roskaft *et al*., 2012), suggesting that the disease was very common and endemic in both agro-pastoral and pastoral communities. Apart from direct physical appearance, water quality is assessed by determining chemical, ecological and microbiological contents, and dissolved oxygen and nutrients (De Troyer *et al*., 2016). However, the interest of this studywas to conduct an analysis of water samples from the ecosystem to determine for the presence of coliforms, which is an indication of faecal contamination from both animals and humans. Subsequent to detection of presence of coliforms, all positive water samples weresubjected for bacterial culture to detect the bacterial species.

The aim of the analysis is to understand the level of risk from contracting enteric infections including typhoid fever, colibacilosis, cholera and other water borne infections to agro-pastoral and pastoral communities in the Serengeti ecosystem.

MATERIALS AND METHODS

Study area

The Serengeti ecosystem spans some 30,000km^2 in northern Tanzania and extends to southwestern Kenya between latitudes 1^O and 4^{O}S and longitudes 34^O and 36^O E. The NCA and LGCA are multiple land use areas where human, livestock and wildlife legally coexist. The ecosystem is featured by annual movements of ungulates, mostly wildebeest (*Connochaetes taurinus*) and zebra (*Equus burchelli*) interacting with other fauna while crossing over the ecosystem from northern Tanzania to the Maasai Mara National Reserve in south-western Kenya. The western side of the Serengeti ecosystem is dominated by agro-pastoral communities which depend on subsistence farming with very limited source of income from surplus crop yield. The eastern side is dominated by Maasai pastoralists who depend to a large extent on livestock as source of income. Livestock and wildlife in the ecosystem interact freely during grazing and watering points, therefore increasing the possibility of interspecies disease transmission.This study was conducted in the Serengeti ecosystem comprising of the Serengeti National Park (SNP), Ngorongoro Conservation Area (NCA), Loliondo Game Controlled Area (LGCA), Maswa Game Reserve (MGR), Ikorongo-Grumeti Game Reserves (IGGRs) and surrounding communities in Bunda, Serengeti, Ngorongoro, Busega, Bariadi and Meatu districts respectively (Figure 1).

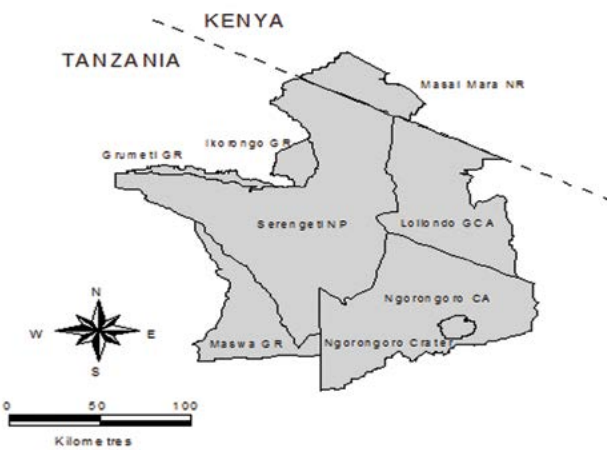

Figure 1: *The Serengeti ecosystem where water samples were collected for coliform test*

Collection of water samples

Many of the community water sources in the Serengeti ecosystem are from shallow open water wells (Plate 1). From each water source about 100ml of water sample was collected using a plastic bottle with a screw cap and stored in cool box for subsequent laboratory analysis.

Plate 1: *One of the water sources in pastoral communities in eastern Serengeti*

Qualitative water sample testing

The collected water samples from the community water sources including streams, springs, shallow and deep wells were subjected to qualitative test to identify samples, which had fecal contamination using Coliforms test kits (200 Sintanjin-ro, Daedeok-gu, Daejeon 306-711, Republic of Korea). The field test kit involved filling the test kit by pressing and releasing the 4ml container with reagents, mixing gently and incubating for 24 hours and observe the colour change. If colourturned yellow it was coliform positive and if it remained colourless it was negative. All positive water samples were then taken to the Microbiology Laboratory at Sokoine University of Agriculture (SUA) for bacterial culture.

Bacterial culture

Bacterial culture was conducted at Sokoine University of Agriculture (SUA), College of Veterinary and Medical Sciences in Morogoro, Tanzania. The water samples were inoculated into MacConkey broth (the positive coliform test) and incubated at 37^{O} C for 24 hours. The broth culture were then sub-cultured into Blood and MacConkey Agar and incubated at 37^{o}C over-night and observed the culture daily for growth and recorded for the colony growth and morphological characteristics of the colonies.The grown colonies were sub-sampled and stored in Slant Nutrient agar for subsequent molecular analysis for the bacterial species present in water sources (Figure 2).

RESULTS

Coliform test kit

During the preliminary test using field coliform test kit, 94 water samples were tested and overall 75 samples (79.8%) tested positive for coliforms.The number of water sources collected on each sampling area and the field kit analyses results are shown in Table 1.

Bacterial culture

For bacterial culture, 61 out of 75 (81.3%) coliform test positive samples had bacterial growth. Of the 61 sample cultures, 11 water samples (18%) had more than one bacterial species growth in one inoculum. The genera of bacterial growth based on colony morphology were five species including *Escherichia coli* (14), *Klebsiella* sp., (30), *Streptococcus* sp., (13), *Proteus* sp., (10), and *Citrobacter* sp., (4) (Table 2). However, molecular analysis is still ongoing at Norwegian University of Science and Technology (NTNU) for species confirmation and describe the bacterial strains.

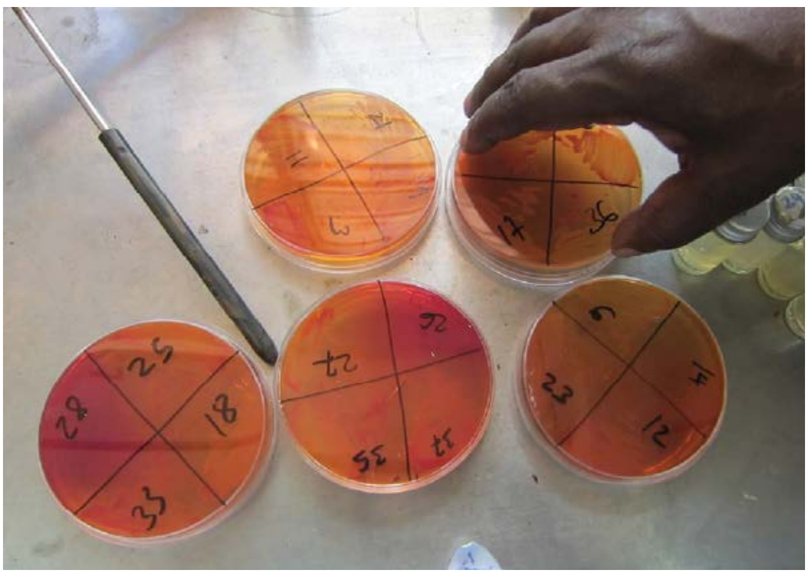

Figure 2: *Bacterial colonies in blood and MacConkey agar and a loop for sub-sampling*

Table 1: Water faecal contamination per village on selected districts or protected areas

District/ protected area	Village or location	Test +ve	Test -ve	Total	Percentage of contamination
NCA	NCAA HQ	7	0	7	100%
	Olbalbal	2	0	2	100%
	Oldupai	3	2	5	60%
	Ngoile	2	0	2	100%
	Misigio	2	0	2	100%
	Losilale	1	0	1	100%
	Endulen	5	0	5	100%
	Laitoli	1	0	1	100%
	Esere	1	2	3	33%
	Osinoni	0	3	3	0
	Onjorio	0	2	2	0
	Koroso	1	0	1	100%
	Orodingoro	2	0	2	100%
	Kakesio	2	0	2	100%
		29	9	38	76%
LGCA	Wasso	1	5	6	16.7%
	Oloipiri	1	2	3	33%
	Sukenya	2	2	4	50%
	Soitsambu	2	0	2	100%
	Ololosokwan	5	0	5	100%
	Arash	5	0	5	100%
	Piyaya	2	0	2	100%
	Malambo	1	0	1	100%
	Engaresero	5	1	6	83.3%
		24	10	34	70.6%
Serengeti district	Park Nyigoti	1	1	2	50%
	Robanda	0	1	1	0
	Malulu-Ikoma	2	0	2	100%
	Fortikoma pump	1	0	1	100%
	Grumeti	1	0	1	100%
	Nkarantare	1	0	1	100%
		6	2	8	75%
Bariadi district	Mwantimba	3	0	3	100%
Meatu district	Makao	5	0	5	100%
Busega district	Ramadi	4	1	5	80%
SENAPA	Naabi	1	2	3	33%
	SWRC	1	2	3	33%
		2	4	6	33%

Table 2: Water sources contaminated with E.coli and risk of exposure to users of the water source

S/N	District/ protected area	Village/ location	GPS coordinates	Positive	Total	Risk of exposure
1	LGCA	Ololosokwan	0759635/9792718	1	5	20%
2	NCA	Oldupai	02.99600S/ 035.35187E	1	5	20%
		Kakesio	03.38377S/ 034.98946E	1	1	100%
		Orodingoro	03.39396S/ 034.99726E	1	2	50%
		Koroso	03.39502S/ 035.01198E	1	1	100%
		Endulen	03.23502S/ 034.24602E; 03.23486S/035.24607E; 03.25203S/035.26645E	3	5	60%
	Meatu	Makao	03.39694S/034.83349E; 03.38298S/034.82366E	2	5	40%
	Bariadi	Mwantimba	02.31553S/034.07421E	1	3	33%
	Busega	Ramadi	02.24068S/033.84495E	1	5	20%
	Serengeti	Malulu-Ikoma	0683014/9769914	1	2	50%
		Fortikoma pump	02.06244S/034.39038E	1	1	100%

Prevalence between communities

The analysis for fecal contamination was stratified to establish the prevalence between pastoral communities in eastern Serengeti and agro-pastoral communities in western Serengeti.

Pastoral communities:

In the pastoral communities for Loliondo Game Controlled Area (LGCA) and Ngorongoro Conservation Area (NCA) about 73.6% of water sources (53 out of 72) had coliforms, of which 8 sources had *E.coli* (Figure 4).

Agro-pastoral communities:

In the agro-pastoral communities of Bariadi, Busega, Meatu and Serengeti districts, about83.3% (15 out of 18) of water sources had coliforms of which 6 sources had *E.coli* (Figure 3). However, the difference in coliform prevalence in water sources in the two community setting was statistically not significantly different (χ^2=0.86; df=1).

Table 3: Location of water source as a risk for contracting enteric infection

Locations	Positive	Negative	Total	Percentage (%)
LGCA & NCA (Pastoralists)	53	19	72	73.6
Bariadi, Meatu, Busega& Serengeti (agro-pasrtoalists& farmers)	15	3	18	83.3
Total	**68**	**22**	**90**	**75.6**

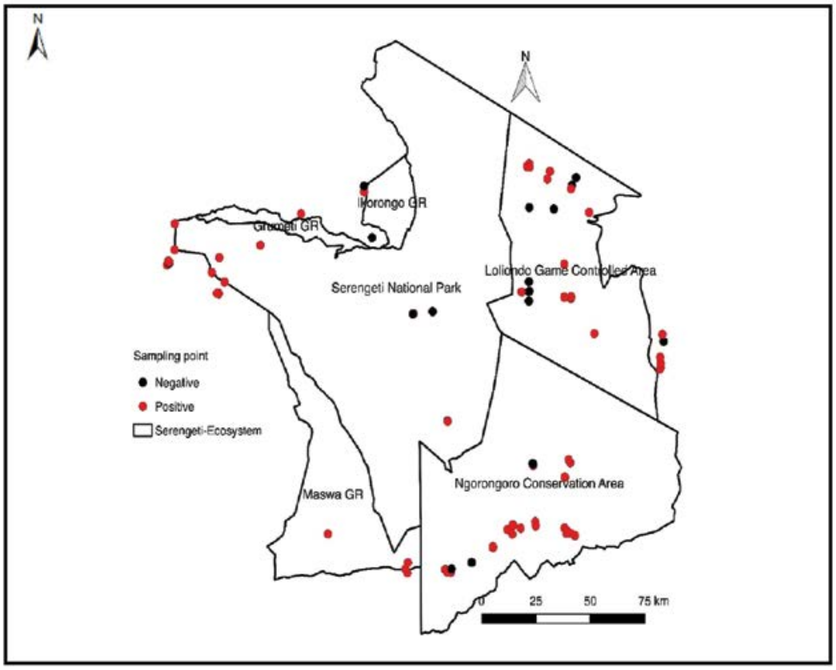

Figure 3: *Sampling location showing coliform test results for the community water sources in the Serengeti ecosystem*

DISCUSSION

This is a first study to establish level of fecal contamination in community water sources in the large proportion of the Serengeti ecosystem. Although water is an important ecosystem service for people and animals, our findings show that water shortage is the greatest problem in the Serengeti ecosystem, and the little water available in these areas is not safe for use without treatment. About 79.8% of water sources were contaminated with faeces, which is extremely high for water sources, which are used by communities. High percentage of contamination suggests that large proportion of agro-pastoral and pastoral community members are at risk of contracting enteric diseases. This calls for an immediate intervention to provide education on the risk of contracting enteric diseases, which are one of the major causes of child mortality in the country (Fyumagwa *et al*., 2017).

Treatment of water by boiling is the simplest and cheap method, however, in western Serengeti, fuel wood is very scarce because of deforestation and lack of initiative in communities to reserve community forest reserves or plant trees in farms where dead wood could be collected by community members or harvest sustainably the planted trees in individual farms. The challenge of sustainable energy source in western Serengeti compels the community members to use untreated water and risk for contracting enteric diseases. However, in eastern Serengeti fuel wood is relatively available adjacent to many communities, however, the pastoralists spent much of the time moving with livestock and have little time to settle and boil drinking water.

Therefore, the eastern and western Serengeti communities are at similar level of risk of contracting water borne diseases, suggesting that water borne diseases contribute significantly to disease burden in the Serengeti ecosystem. Presence of *E.coli* in community waters suggests that there is high possibility for other zoonotic enteric bacteria to cause disease outbreak including *Vibrio cholera* that causes cholera, a highly fatal enteric disease that causes high morbidity and mortality in affected community.

In western Serengeti, communities construct pit latrines but are not routinely used by household members. These latrines are constructed to avoid fines by public health officers during routine health inspection in communities. It is also a taboo for adult members in the household not to share the latrines with children especially girls or in-laws (WHO and UNICEF, 2012). In these communities routine use of latrines is questionable, therefore, there is very high risk of contamination of water sources with human faeces leave alone from animals. This is evident from high percentage of coliform test positive water sources. However, in eastern Serengeti, the pastoralists rarely construct pit latrines because of nomadic nature. Therefore, lack of latrines and failure to use them where they are available is the major source of faecal contamination in water sources and such practices have caused high fecal contamination. The Serengeti ecosystem has the highest concentration of wild animals including herbivores, carnivores and non-human primates (Sinclair and Arcese, 1995), therefore, the faecal contamination in many of the water sources was not only from human excretor but also from wild animals. About 23% of water sources had *E.coli*, which is a deadly bacterium that produces enterotoxin that causes food poisoning especially when this water is used for watering vegetables in gardens, washing fruits and direct drinking. The observation is in conformity with what Roskaft *et al*. (2012) established in the agro-pastoral and pastoral communities where it was found that about 10% of the population in these communities succumbed to diarrhea/ and or dysentery every year. From our observation in this study it is obvious that contaminated water sources is one of the contributing factors for the reported diarrhea/ and or dysentery in agro-pastoral and pastoral communities in the Serengeti ecosystem. In the analyses 16.4% and 6.6% of positive cultures for bacteria was due to *Proteus* and *Citrobacter* species respectively, which causes enteric diseases as well, suggesting that the level of contamination of many of the water sources was very high both in eastern and western Serengeti. Presence of *Klebsiella* sp., (49.2%) and *Streptococcus* sp., (21.3%), suggests that people wash their bodies in the same water sources, which are used for domestic use and also the same water sources are shared with animals.

The Serengeti ecosystem is an important source of water, which is used by people and millions of wild animals and livestock. For this ecosystem service to be of value it must be of acceptable quality. Therefore, efforts must be taken by the government, management authorities and conservation stakeholders to provide potable water sources in agro-pastoral and pastoral communities in the Serengeti ecosystem.

CONCLUSION AND RECOMMENDATIONS

Knowing that the level of contamination of community water sources is very high, we recommend that more research is required to have a broader understanding on diversity of water borne diseases pathogens in the Serengeti ecosystem.

In understanding that energy source for treating water by boiling is a serious problem in communities in the Serengeti ecosystem, we recommend that applied research should be conducted to develop cheap water treatment equipment or filters.

Given that the level knowledge on risk of contracting water borne diseases is very low among community members in the ecosystem, we recommend that Management authorities and district authorities should invest in awareness creation to communities with regards to health risk in using untreated water. Similarly, awareness creation on the importance for boiling drinking water to at risk communities should be implemented by the relevant authorities.

ACKNOWLEDGEMENTS

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WETLAND RESOURCES AND PRINCIPLES GUIDING UTILIZATION: A CASE OF BAHI WETLAND DODOMA REGION, TANZANIA

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ABSTRACT

This study was done to investigate Bahi wetland resources and principles guiding utilization in Dodoma Region, Tanzania. Specifically it examined wetland resources utilization practices and principles guiding its utilization in Nagulo Bahi and Bahi Sokoni Villages. A cross-sectional research design was employed to collect information through focus group discussions, key informant interviews, non-participant observation and documentary review. The data was analyzed using content analysis. In addition, data of rainfall and temperature from Bahi District downloaded from National Centre's for Environmental Prediction and Climate Forecast System were analysed. Furthermore, remote sensing data were analysed to assess the dynamic change of the Bahi wetland. Results revealed that Bahi wetland is mainly used for paddy cultivation, fishing, livestock keeping and vegetable production. Paddy farms are under improved irrigation scheme using improved canals at Bahi Sokoni Village and locally established canals mainly at Nagulo Bahi. Both two types of constructed canals are not lining with concrete, causing erosion, loss of water through percolation and siltation in lower parts of the wetland. There are no demarcated areas for grazing; animals scatter all over the wetland sometimes damaging irrigation infrastructure. Some fishers conduct fishing in the lake without permission and/or license or paying taxes and important fees in the ward office; use illegal gears such as under mesh size and sometimes mosquito nets which capture both immature fish and fish eggs. Fishery officers have taken initiatives to burn under size mesh net and taxes and registration fees were introduced in 2016 for fishing vessels, fishers nets and business men. However, inadequate awareness of the by-laws guiding utilization of resources and the lack of by-laws' enforcement have resulted into poor utilization of wetland resources, leading to wetland degradation. The impact of climate change is exaggerated by improper human activities in the wetland. Data analysis from satellite images were analyzed and indicates significant decline of water surface area in the wetland and also area covered by water over years. Therefore, awareness creation to improve understanding of community and enforcement of existing bye-laws using a more focused and sectoral integrated efforts are the vital measures to safeguard Bahi wetland.

***Key words**: Bahi wetland, guiding principles, laws and by-laws, resource utilization.*

INTRODUCTION

Wetlands are worldwide recognized for their ability to support human being. They have significant economic, social, cultural and biological values that are essential for the welfare of the community living near them (Kamukala & Crafter, 1993; URT, 2014; Marambanyika & Beckedahl, 2017). Wetlands are the major sources of water and pastures for livestock, fishing and agricultural activities, which significantly contribute to the economy and livelihoods of communities (Yanda *et al.*, 2007; Majule, 2009; URT, 2014).

Although wetlands are potential they are dynamic ecosystems, changing naturally over time as a consequence of processes such as erosion, siltation and coastal flooding (IWMI, 2014). Human activities such as agricultural activities either within the wetland or in the catchment accelerate degradation and loss of these potential resources (Hoozemans *et al.,* 1993; Majule, 2009; IWMI, 2014). Other factor such as climatic change has impacted and is expected to intensify the pressure on wetlands due to rainfall variations that have resulted into floods and drought. Coastal areas are already at risk of flooding from sea-level rise and it is estimated that 22% of coastal wetlands could be lost by 2080 (Hoozemans *et al.,* 1993; IWMI, 2014).

Although human activities, climate change, etc., contribute to wetlands degradation, unguided utilization of wetland resources is identified as a key factor influencing wetlands degradation and loss in most developing countries including Sub-Saharan Africa and Tanzania in particular (Majule, 2009; Marambanyika & Beckedahl, 2017). For instance, in Tanzania, Usangu wetland and Babati Lake resources are deteriorating due to population pressure which is causing people to demand more agricultural land. Various initiatives have been done to restore and preserve wetlands of which the most significant is the Ramsar Convention on Wetlands that was established in 1971 in Iran. The Ramsar Convention on Wetlands initially aimed to conserve wetland ecosystems, in particular for their importance as a habitat for birds, preserving them for wildlife and conserving the environment (Ramsar, 1971 in Kamukala & Crafter, 1993). However, focus on conservation alone denies rights for the communities residing near the wetlands to benefit from other resources existing in the wetlands. The Ramsar Convention on Wetlands (2010) has then shifted focus, advocating a key aspect of the principle of 'wise use' that seeks to protect wetlands not only for their value to wildlife, but also for the benefits they provide for humans, particularly people living in poverty. The signatories to the Ramsar Convention on Wetlands (Tanzania included) are obliged to promote the wise use of all the wetlands in their territory (IWMI, 2014; Marambanyika & Beckedahl, 2017).

Tanzania is the largest country in East Africa that has a significant proportion of wetlands estimated to be 10% of its total surface area. The wetlands include the great lake system, inland drainage systems, major river networks and deltaic mangrove areas (URT, 2014). The area covers 1,000 km of the Indian costal line with a highly indented coastline, a shore of 305 km on Lake Nyasa in the southwest and another of 650 on Lake Tanganyika in the west. In addition, to the northwest 1420 km of Lake Victoria's shoreline also lies in Tanzania and there are swampy basins and flood plains wetlands (NEMC/WWF/INCU, 1990). In the country wetlands play important role as they are known to be nature's water store on land, of which, almost 95% of all water on land providing vital ecosystems support services for humans, wildlife and livestock is stored in wetlands. They are the source of power (electricity), control of floods, retention, prevention of eutrophication of rivers and lakes, groundwater recharge, supporting specific bio-data and traditional uses. They are also particularly important in semi-arid areas where they play a significant role in providing water and water related resources for various purposes especially during dry season (URT, 2014).

Although wetlands contribute substantially to livelihoods and socio-economy of Tanzania, unguided utilization of wetlands resources including destructive fishing methods, deforestation, overgrazing and other human activities taking place in the catchments of rivers are among the main sources that interfere with the potentials of wetlands including Bahi wetland. Bahi wetland is important for the Bahi community living near the area and Tanzania as a whole, as it provides area for farming, grazing, fishing, etc. (Kamukala & Crafter, 1993; Yanda *et al.*, 2007; URT, 2014). Various efforts have been done by the government of Tanzania to safeguard wetlands including formulation of a guideline aiming to provide for sustainable management of wetlands that would contribute to: i) Improve livelihoods while maintaining ecosystem functions; ii) Facilitate and provide a framework for sustainable management of wetlands that includes other important policies such as National Agriculture Policy (2013), National Water Policy (2012), National Fisheries Sector Policy (2015), Tanzania National Wildlife Policy (1998), Forest Policy (1998), Land Policy (2005), National Environmental Policy (1997) and Livestock Policy (2006); and iii) Maintain essential ecological (URT, 2014). These efforts are vital when considering increased demand for wetland resources due to increased population and the threat of degrading the area when utilization of resources is not properly guided. Thus, the concern is on how Bahi wetland resources are utilized and whether these policies and guideline have been operationalized for them to be implemented at the grass-root.

Problem statement

Tanzania is very rich in wetland resources which include the Great lake systems, major river networks and deltaic mangroves. The major lakes and floodplains have long provided a fertile resource base as they include alluvial plains of great agricultural potential. Wetlands in Tanzania support an extensive trading and transport system, fishing grounds, agro-pastoral activities, hydrological processes and, more recently, the harnessing of the river flows for irrigation and hydroelectric power. Bahi Wetland in the central part of Tanzania is not different from other wetlands, as it serves livelihood of many people. The livelihoods of these people rely on Bahi wetland for a variety of goods and services, such as the harvesting of resources (forest, forage and fish), crop farming, livestock grazing and water supply (Dugan, 1990; Majule & Kalonga, 2009). However, little is known on how the wetland resources are utilized by the community and principles guiding utilization for sustainable future use (URT, 2014).

Though Tanzania is concerned with management of wetlands and has formulated the guideline on sustainable management of wetlands to show its commitment on ensuring that wetlands are effectively conserved (URT, 2014), the wetland areas are still degrading including the Bahi wetland, which the rate of degradation is increasing consecutively. The level of siltation is increasing which is leading to decrease in water levels. The situation raises questions as to how the Bahi wetland resources are utilized and whether there are principles guiding resources utilization. Various studies done on Bahi wetland have focused on the hydrology of the Bahi wetland (McCartney, 2007) and impact of climate change on livelihoods in wetland resources (Majule, 2009). Studies focusing on Bahi wetland resources and principles guiding its utilization are inadequate. Due to this situation, Bahi is among of the endangered wetland in Tanzania that requires investigation. The study therefore aims to fill this gap of information by investigating wetland resources' utilization and practices guiding utilization in Nagulo Bahi and Bahi Sokoni villages of Bahi District in Dodoma Region, Tanzania. Bahi wetland is important for the survival of community surrounding the wetland. It is a main source of food and income. Therefore, utilization of its resources should be guided to avoid deterioration and assure proper resources utilization due to: Increased population that depends on the wetland, threats due to climate change and the fact that, Bahi wetland has potential resources that can contribute to the movement of Tanzania to industrialization.

RESEARCH METHODOLOGY

Study area

The Bahi wetland is a shallow ephemeral lake located in central Tanzania, approximately 60 km north-east of the city of Dodoma Region, Bahi District (McCartney, 2007) (Fig 1). Dodoma Region is situated in a semi-arid area, having a dry savannah type of climate characterized by long dry season, unimodal and erratic rainfall that falls between November or December and April. Bahi District has an annual average rainfall of about 500 to 700 mm and an annual average temperature of about 22.60C (URT, 2003). The Bahi wetland is located within the Bahi depression, a down-warped section of the Eastern Rift Valley, between latitudes 05^{o}51' and 06^{o}20' south and longitudes 34^{o}59' and 35^{o}21' East. The lake has a surface area of approximately 974 km2 and lies at an altitude of 830m.a.s.l. There is no outflow from the lake, which consequently varies considerably in size depending on precipitation in the catchment area. In some years the lake dries completely.

The Bahi wetland receives water from various seasonal rivers, mainly draining from the north (Kondoa and Babati). Of these the Bubu and Mponde are the largest. Other rivers flowing into the lake are the Lawila, Nkojigwe, Msemembo, Maduma and Zuboro. The total catchment area of the lake is 23,447 km^2. All the rivers are ephemeral, usually ceasing to flow during the dry season (i.e. May to December) (McCartney, 2007). Communities surrounding Bahi wetland including those from Nagulo Bahi and Bahi Sokoni Villages utilize the wetland for cultivation, livestock keeping and fishing (Yanda *et al.,* 2007).

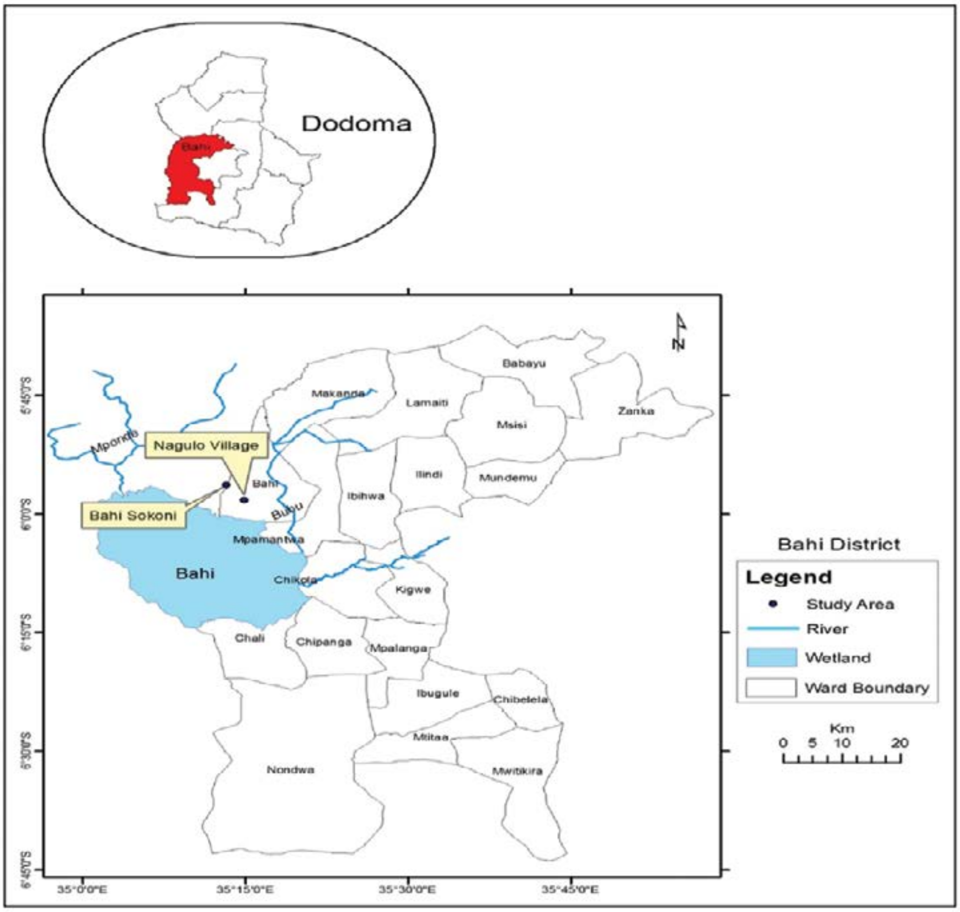

Figure 1: *A map showing study area.*

Research approach, design and data collection methods

This study employed a qualitative research approach and a cross-sectional research design. The design is considered appropriate as it uses descriptive data collection methods that allow direct observation of the events to be studied and interview of the persons involved in the events (Kothari, 2004).

The data was collected only once from the individuals living in Nagulo Bahi and Bahi Sokoni Villages and officials important to the study through the key informant interviews (KIs) and focus group discussions (FGDs). Other methods employed were non-participants observation and documentary review.

The key informants including one Irrigation officer, two livestock officers, three officials from fishery department, two agricultural extension officers, ward and village leaders and 30 individual farmers were interviewed. Other key informants interviewed were Bahi District director and community development officer from the District. Focus group discussions were conducted by involving women and men both youth and adult people. There were four focus groups (two groups for women and another two for men aged above 18 years old). The focus groups discussions comprised of 7 - 8 people (Kothari, 2004).

Information collected from the focus group discussions were focused on the wetland resources utilization and the identification of principles guiding resources utilization. Various documents related to wetland resource utilization and principles guiding resources' utilization were reviewed to provide better understanding of the wetland resources utilization. The document reviewed included published and unpublished reports related to wetland resource utilization. Field visit were conducted to view different activities conducted in the wetland and how human activities contributed to wetland degradation and measures taken by the community to protect the wetland.

Data processing and analysis

The qualitative data was analyzed by using content analysis whereby the information collected from FGDs and KIs was summarized, translated and categorized into various themes.

The images used were acquired by the satellite in January and February in which the wet season has reached its peak in the study area.

Remote sensing data analysis

In order to understand the dynamic change of Bahi wetland images were downloaded from United State Geological Survey (USGS) website of different years (Table 1).The images include LandSat 4, 5 and 8 data sets.

RESULTS AND DISCUSSIONS

Wetland resources' utilization by the community of Nagulo Bahi and Bahi Sokoni Villages

Different activities are carried out by the community living in Nagulo Bahi and Bahi Sokoni Villages in the wetland. The activities depend on the season because water availability varies with time within a year. For instance, river Bubu and Mponde release enough water from December/January to May/June which enhances irrigation in under paddy farms and fishing in the lake. However, from July to November, the level of water decreases and in some years the lake dries completely.

Table 1: Images of LandSat from 2010 to 2017

Date of scene	Path/Row	Satellite	sensor	Spatial resolution (meter)	Source
2000	169/64	LandSat 4	TM	30 * 30	USGS
2010	169/64	LandSat 5	TM	30 * 30	USGS
2017	169/64	LandSat 8	OLI	30 * 30	USGS

The Normalized difference water index (NDWI) was calculated as suggested by Mcfeeters (1996).

$$NDWI = \frac{\text{Green - Near Infrared Band}}{\text{Green + Near Infrared Band}}$$

This formula was used to compute for NDWI – water mapping in Bahi wetland

The result of NDWI range from -1 to 1, whereby -1 shows no existence of water body while 1 show existence of water body.

Therefore during dry seasons, community evolve in other activities apart from paddy cultivation and fishing. The major economic activities carried out in Bahi wetland are paddy cultivation, fishing and livestock keeping. Other activities are vegetable production, petty business and handcrafting by using wetland grasses that is used to make local carpets and baskets.

Irrigation practice for paddy production

Bahi wetland is used for food production to the surrounding community through rice cultivation and sometimes surplus production, as a source of income. There are two types of irrigation practiced in the study area i.e. irrigation under scheme which is practiced in Bahi Sokoni Village and local irrigation practiced by the farmers who are not under the irrigation scheme including farmers from Nagulo Bahi.

The two rivers (Bubu and Mponde) feeding Bahi wetland are used directly by farmers both in the upper (Bahi Sokoni) and lower part (Nagulao Bahi) of the rivers. Traditional irrigation is constructed locally by farmers.

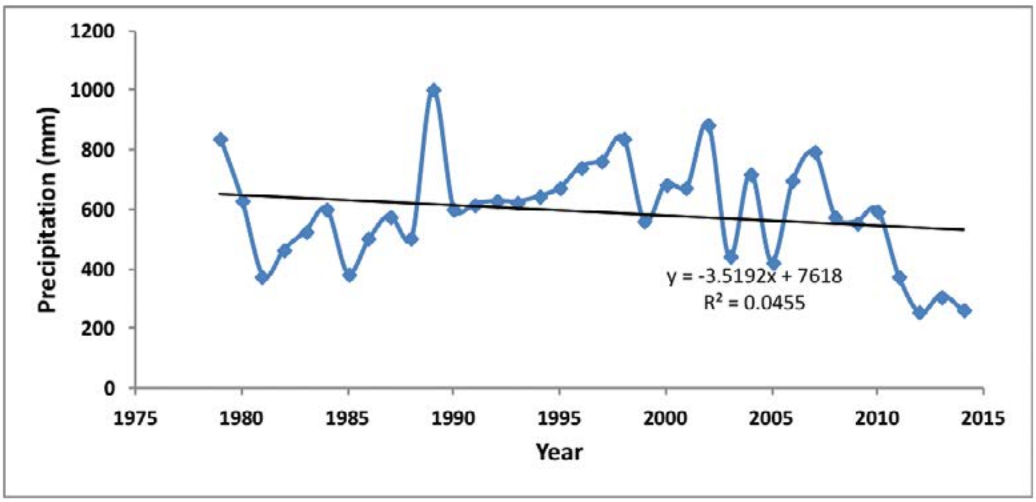

Figure 2: *Variation of rainfall over the period of 30 years. Sources: The National Centres for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR).*

Farmers establish small canals from the river and wetland to their farms. Another type of irrigation is by extending big canals to the farms. However, the canals of both two types of irrigation (tradition and through scheme) are not lining with concrete. Inadequate construction of irrigation canals has led to erosion, loss of water through percolation and siltation in lower parts of the wetland. The siltation has caused decrease of lake size and area covered by water in the wetland In most cases, farmers were also complaining about unreliable and shortage of rainfall. The information were also justified through analysis of rainfall data which shows decreases of rainfall over the past 30 years (Fig 2).

Fishing activities in the wetland

Fishing is the second income generation activity after paddy production that is carried out by fishers from surrounding villages including Nagulo Bahi and Bahi Sokoni, also fishers from outside the Bahi District (e.g. from Arusha, Singida, Mwanza, etc.). The fishing takes place in the wetland from April to September and it varies depending on the level of precipitation in the catchment area. For example, in 2003 the wetland dried completely and also in this year (2017). This has led to massive deaths of fish. Conversely, during El Niño (1997/98) water accumulated in the wetland for almost four consecutive years. However, in the normal circumstances all the rivers stop flowing from May/June to November/December during dry season. The dry out of the wetland is exaggerated by the types of irrigation conducted in the wetland and also overstated by increasing in temperature caused by climate change that has led to high evaporation rates. Temperature data was assessed and revealed an increase in both maximum and minimum over the past 30 years (Fig 3a & b).

The findings are in line with Swai *et al.* (2012) who found that the mean minimum and maximum temperature for the period

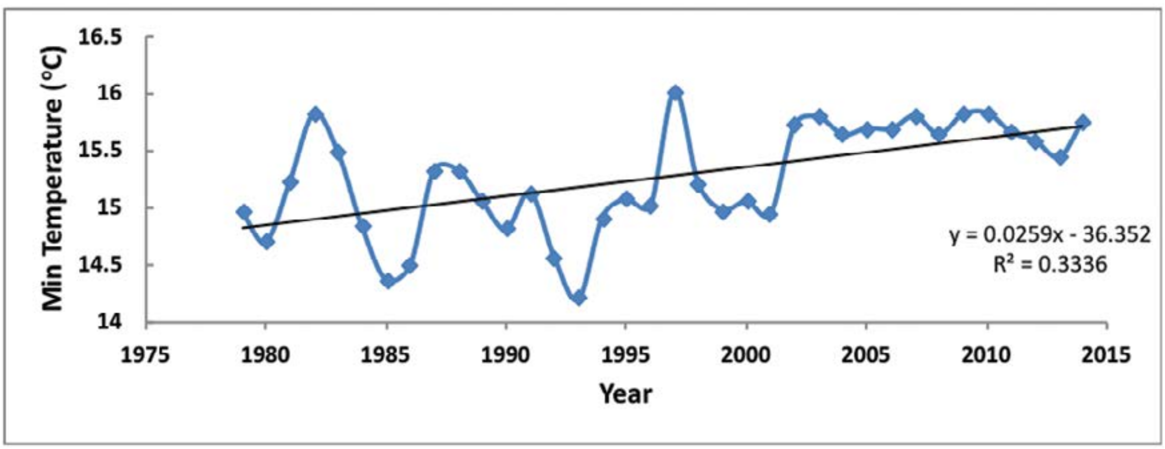

Figure 3b: *Variation of minimum temperature over the period of 30 years. Sources: The National Centres for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR)*

of 30 years (i.e. 1970 to 2010) in Bahi District had increased. December to March is an incubation period where fishing is restricted to allow fish to grow. However, the fishers do not adhere to this regulation and enforcement is inadequate due to the lack of man power and infrastructure. For instance, during key informant interview Fishery Officer said that:

> *"It's very difficult for two Fishery officers to monitor fishing process in the whole lake during the day and night because most of the fishing activities are also conducted the during night"*

In addition, there is no specific committee or institutions that monitor fishing practices in the lake apart from those two fishery officers. Due to inadequate monitoring, fishers conduct fishing in the lake without permission and/or license and even without paying taxes. During key the informant interviews it was revealed that fishers are using illegal gears such as under mesh size and sometimes mosquito nets which captured both immature fish and fish eggs. According to section 43 (4) of the fisheries Act Tanzania of 2003, it is illegal to use nets less than 127 mm (holes size) when diagonally straight. The fishers are aware about the impact of using such gears in fishing, but this law is not enforced.

Livestock keeping

Other important services provided by Bahi wetlands include provision of water and grazing for livestock such as cattle, goat and lamb. Wetland is considered as important resource for grazing and especially in semi-arid areas, including Bahi District during dry season. Inappropriate grazing practices in the wetland are among the causes of wetland degradation. For example in Bahi wetland there are no demarcated areas for grazing. The animals scatter all over the wetland sometimes damaging irrigation infrastructure and livestock keepers do not consider grazing as the major threat to the wetland. During dry season when the water is scarce, livestock herders and vegetable growers construct shallow wells to provide water to the livestock and irrigation. This practice of constructing shallow wells has negative effect on wetland, as during rain season the soil extracted from those wells is washed out and cause siltation in the lower part of the rivers.

Principles guiding utilization of resources in Nagulo Bahi and Bahi Sokoni Villages

In any wetland, principles guiding utilization of resources are paramount. For examples, in Tanzania there are guidelines and policies intended to regulate resources utilization and management. Most of these guidelines and policies are in the National level that requires to be translated for implementation at lower levels (district, ward, village, etc.). Some of the community members of Bahi District are aware of these regulations, but utilization of resources and management lack by-laws' enforcement. During interview with one of the key informants (Ward Executive Officer), he said that:

> "*There are by-laws guiding the resources' utilization in our wetland, but the laws lack enforcement due to the shortage of human resources and infrastructures".*

During focus group discussion and key informant interviews it was revealed that most of the communities surrounding the wetland were aware of some of the regulations and laws guiding wetland resources' utilization. Nevertheless, the wetland is the major source for pasture and water in semi-arid areas. This condition force to utilize resources against the regulations and laws. It was revealed that different sectors such as fisheries, livestock, agriculture and irrigation to safeguard the wetland. For example, fishery officers have taken initiatives to burn under size mesh net and taxes and registration fees were introduced in 2016 for fishing vessels, fishers and business men.

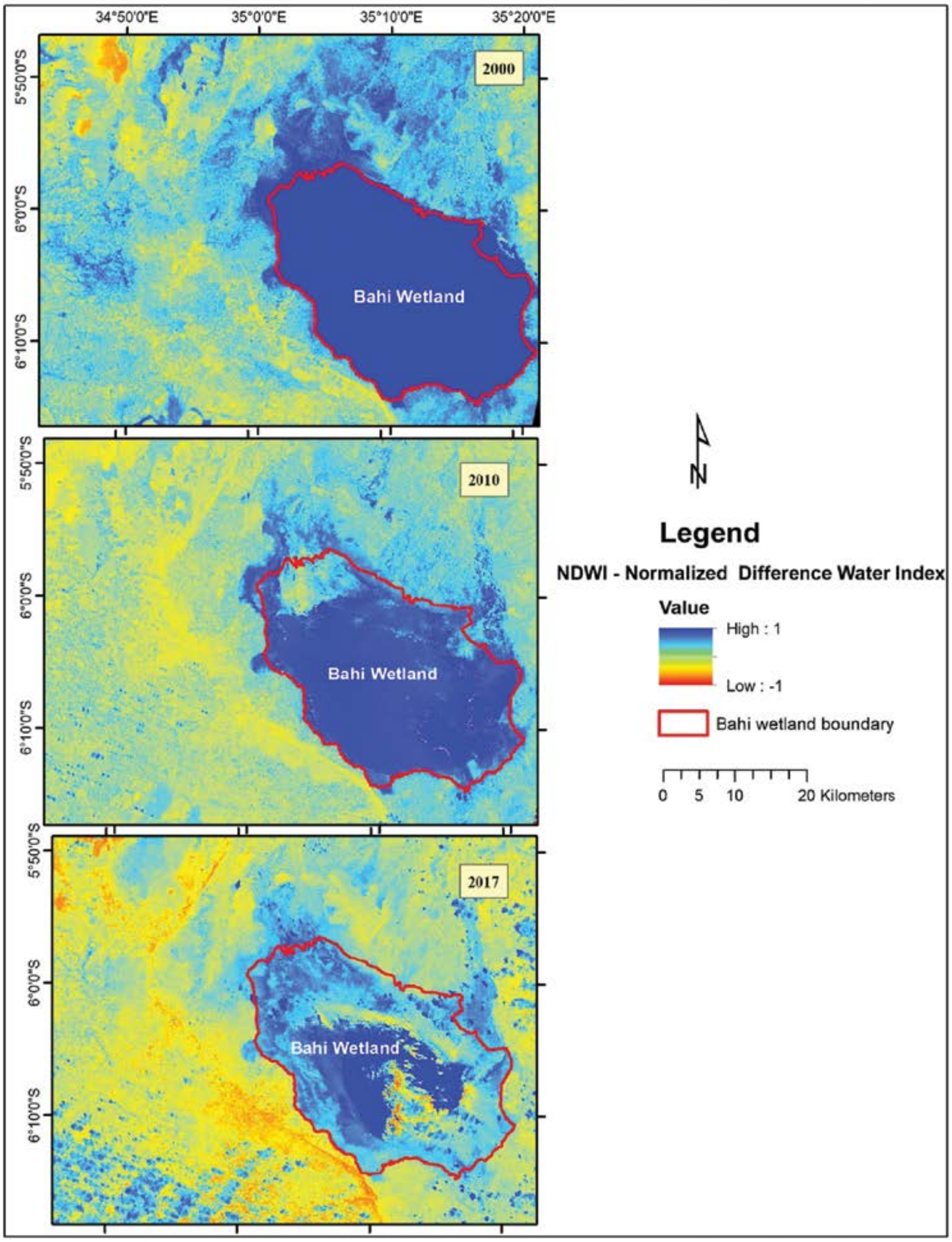

***Figure 4**: Satelite images of 2000, 2010 and 2017.*

Table 2: Water surface area index.

Year	Water surface Area (km^2)	Change (Km^2) 2000 - 2010	Change (km^2) 2010 - 2017
2000	783.39	-644.32 = -82.25%	-19.81 = -14.24%
2010	139.07		
2017	119.26		

various measures had been undertaken by The money collected from taxes and fees was allocated to various activities through the district budget. In addition, livestock sector had also introduced taxes during selling of livestock while irrigation sector introduced improved irrigation scheme, though the canals used were not lining with concrete. However, inadequate coordination among these sectors and other institutions dealing with the wetland management is among the causes that have resulted into poor management and utilization of wetland resources leading to lake degradation.

The impact of climate change includes shortage of rainfall and increased in temperature are exaggerated by improper human activities in the wetland area. Lack of law enforcement in resources utilization leads to erosion and siltation in the lake and that had effect already on water level and size of the lake. Through analysis of satellite images, result indicates that spatially the water surface area in bahi wetland has significantly declined over years (Fig 4). The water surface area declined from 2000, 2010 and 2017 (Table 1).

Similarly, between 2010 and 2017, more area covered by water had declined (Table 2, fig 5). This could be attributed by increasing of improper human activities in the wetland such as irrigated rice farming ,overgrazing and over utilization of water in upper part of the rivers which feeds the wetland.

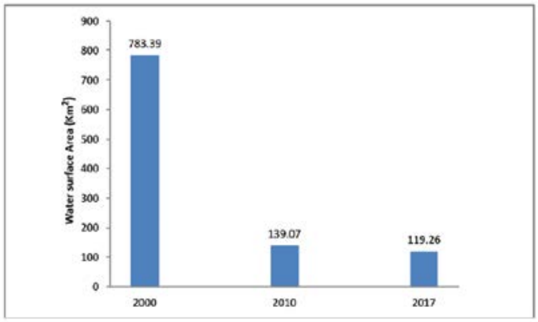

***Figure 5**: Variation of area covered by water from 2010 to 2017.*

CONCLUSION AND RECOMMENDATIONS

Community of Nagulo Bahi and Bahi Sokoni Villages utilizes various resources from the wetland including paddy and vegetable cultivation, fishing, grazing and water for livestock. However, inadequate awareness of the by-laws guiding utilization of these resources and the lack of by-laws' enforcement have resulted into poor utilization of wetland resources which has led to siltation in the lower part of the wetland. In addition, the impact of climate change including increases in maximum and minimum temperatures and decreases in rainfall have exaggerated in decrease the size of the lake and the area covered by water in the wetland. Therefore, using proper regulations and laws to guide utilization of Bahi wetland resources is paramout. This is possible if the awareness will be created to the community and enforcement of existing by-laws will be taken serious, using a more focused and sectoral integrated efforts.

National laws should be translated to the lower levels (district, and village levels) and by-laws should be established at local level. By-laws should be enforced in collaboration with village committees, ward leaders, community based organizations, NGOs and other governmental institutions including agriculture, environment, irrigation and fisheries sectors. Enforcement of by-laws will enable Bahi District to collect more money through imposed taxes, fees and even fines. This can be achieved by increasing the number of important experts in wetland management and improving of infrastructure. For instance, money collected from Bahi wetland is allocated the money to various District activities through its budget. However, the money could have been used directly to manage the wetland by improving infrastructure, providing fuel for patrol, etc.

In addition, land use planning in Bahi wetland is crucial to demarcate grazing areas, crop cultivation, etc. This will also indicate buffer zones to protect the wetland. The size of the lake is decreasing and area covered by water in the wetland is also decreasing consecutively. Dredging is important to increase the depth of the lake in order to allow enough accumulation of water throughout a year. This will prevent massive deaths of fish, increase fishery production and the income of people of Bahi District. In order to control re-siltation in the lake, irrigation canals should be lined with concrete.

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COMPARISON OF WILDLIFE NUMBERS IN TARANGIRE ECOSYSTEM USING AERIAL AND GROUND COUNTS

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ABSTRACT

We compared the results of wildlife counts across the Tarangire ecosystem using two methods: Systematic Reconnaissance Flight and ground counts using DISTANCE analysis. The counts took place across the same area within a month of each other in the dry season (October-November 2016). The counts focussed on six large mammal species that form the majority of the mammalian biomass in the ecosystem (Zebra, Wildebeest, Giraffe, Grant's gazelle, Impala and Elephant). The two count methods showed similar figures for Zebra, Wildebeest, Grant's gazelle and Elephant. Figures for Impala showed large disparities in ground count figures. Undercounting of Impala may be a common feature of aerial counts, as the animals are relatively small, well camouflaged from above, and typically live in dense bushland. These data suggest that ground counts could be used more frequently as a cost effective method of establishing wildlife numbers and trends. Using aerial counts to calibrate ground counts should also be considered.livestock breeds with exotic stock, can cause the degradation of ecosystem services.

Key words: *Aerial counts, Ground counts, wildlife counts, Tarangire ecosystem.*

INTRODUCTION

Northern Tanzania supports some of the most important large mammal populations on the planet (TAWIRI, 2006a, b; TAWIRI, 2007a, b, c; Mduma et al., 2010; Pettorelliet al., 2010), which form the basis of a thriving wildlife tourism industry that heavily supports the national and local economy. A key feature of wildlife populations across northern Tanzania is that they are highly mobile, often migrating large distances annually to obtain food and water. This is particularly true in the Tarangire ecosystem, where the wildlife populations in the ecosystem migrate large distances across community lands every year, in response to the short and long rains(Galantiet al., 2006). In the late 1980s, this migration was estimated to involve approximately 80,000 animals, making it the third largest large mammal migration in East Africa, after the wildebeest in the Serengeti and the kob in South Sudan (Foley &Foley, 2014).

Determining wildlife numbers and trends

is important for protected area managers operating across the ecosystem; it allows managers to identify a variety of potential problems such as poaching, over-hunting, disease outbreaks, or loss of important dispersal areas, and to take appropriate counter measures where possible (Kumara et al., 2012; Ransom et al., 2012; Andersonet al., 2013; Rouse et al., 2014, Morrison et al., 2017). The Conservation Information Monitoring Unit (CIMU) of TAWIRI has been conducting aerial censuses across Tanzania for over 30 years. Two types of censuses are usually carried out: Systematic Reconnaissance Flights (SRF) and Total Counts (TC). In the former, a percentage of the ecosystem is flown, and numbers of wildlife extrapolated to cover the entire ecosystem (Douglas-Hamilton, 1996; Omondi et al., 2005; Craig, 2012). In TC's, flights are assumed to cover the entire survey area, and that all animals within that area are recorded (Norton-Griffiths, 1978). TC'saretypically used for animals such as elephants and buffalo, that aggregate in large herds, which can lead to over-estimates using the SRF method, which assumes even distribution of wildlife across a survey area(Norton-Griffiths, 1978). The challenge with both TCs and SRFs is that they can be very expensive to carry out (Rachael et al., 2012; Lobora, 2017). An SRF of the Tarangire ecosystem for instance, can cost over $60,000 to complete. Surveys might therefore only be carried out once every 3-10 years, depending on the availability of funds. It is important therefore to find other, more cost effective methods of counting animals across a large survey area that can be conducted more frequently with the small budgets typical of protected areas.

Distance sampling (DS) surveys along line transect are widely used for estimating density and abundance of wildlife populations (Buckland et al., 1993, 2001; Koenenet al., 2002; LaRue et al., 2007; Kumara et al., 2012; Anderson et al., 2013). Standard DS assumes that animals are uniformly distributed with respect to the transect line and if there are fewer animals on or near these lines, then this can cause biases in the estimates of density and abundance (Thomas et al., 2010). Ideally transects would be selected at random throughout the survey area so that there is no inherent transect bias. However, covering large areas of land, parts of which may be difficult to traverse, or inaccessible to a vehicle, means that DSs are often carried out along roads and tracks. For many species, it may be difficult to obtain sufficient sample sizes to reliably estimate detectability if transects are not carried out along roads. Depending on the particular characteristics along a stretch of road one might expect that animals potentially avoid the area directly on or near the road to a smaller or larger degree. Given that road counts are widely used in northern Tanzania, investigating these issues is particularly pertinent to wildlife monitoring more broadly. Here we compare the results of an SRF and a road-based DS count carried out within a month of each other during the dry season 2016.

METHODOLOGY

Ground counts

We carried out a ground count in October 2016 using Distance sampling techniques. Distance sampling surveys along line transect are widely used for estimating density and abundance of wildlife populations across large geographic areas. The method is effective and efficient for monitoring multiple species across a large landscape such as the Tarangire ecosystem. A distance sampling (DS) surveywas conducted along approximately 1,500 km of roads within the Tarangire ecosystem from Makame to West Kilimanjaro. The data were then extracted to cover only the areas that were surveyed by the SRF count.

The surveys were vehicle-based, using two different survey teams each comprised of a driver, a left seat observer and a right seat observer. During the survey, observers moved along pre-set road transects. Wildlife sightings on the road were monitored by the driver, while the observers recorded animals on their respective side of the vehicle. During each of the surveys,the teamscovered the areas of MakameWildlife Management Area, Simanjiro, Tarangire National Park, Lake Manyara National Park, Manyara Ranch, RandelinWildlife Management Area, Lake Natron, EnduimetWildlife Management Area, and BurungeWildlife Management Area. Transects were started at approximately 7:00 am until around mid-day, and then again from 3:00 pm to dusk. This was done to avoid the hottest hours of the day when wildlife activity is at its lowest. Although data were collected for a large number of species, we focus on the results for our six target species, namely elephant, giraffe, impala, Grant's gazelle, wildebeest, and zebra. All animals seen were identified to species, counted, and their location recorded by Global Positioning System (GPS) point. The perpendicular distance from the transect line to the center of the animal group was also measured using a rangefinder (otherwise, if a group of animals was spread over a large area, the distances to the animals delimiting the outer edge of the group with respect to the road were measured and the distance to the group'scenter calculated prior to analysis to accurately determine the centre point of the group). Animals over 50 meters apart were considered to be a different group. If the sighted animals moved prior to the vehicle drawing parallel to them, the perpendicular distance was measured from the location where they were first seen. The track log for each transect was recorded by GPS and downloaded at the end of the survey.

Vegetation type and visibility were recorded every 2 km and this information has been associated with each observation using a spatial query. This allowed an investigation on whether detectability is significantly influenced by factors such as group size, habitat type, and visibility using Multiple Covariate Distance Sampling (MCDS). This enables us to understand how variables affect detectability andavoid potential bias and can improve precision. During the standard distance analyses separate detection functions were fitted per survey, but the data were pooled across survey strata.

Encounter rate and group size were stratified by survey stratum. In the majority of cases average group size per stratum was used, as the regression of the natural log of group size against distance was not significant (at the 15% alpha level), indicating that there was no size bias in estimation of group size. The global density estimate was calculated as the mean of the stratum estimates weighted by stratum area.

The density and distribution of the various wildlife species of interest may be different within the area sampled along the road compared to the areas further from the road. For this reason, we avoided extrapolating to the broader landscape, but just focused on areas well covered during the road surveys to avoid biasing the results (Figure 1). For example, although Tarangire National Park covers an area of 2,633 km2, we used the smaller area of 1,884 km2 that excluded the southern 28% of the national park (NP) not covered during the road surveys. Thus, for elephants found predominantly in the northern portion of Tarangire NP (based on aerial survey assessments covering the entire landscape and other research in the NP), if this were not done the estimates of abundance would be in the region of 28% larger. A key assumption underlying distance sampling is that detectability on the line is certain (Thomas et al., 2010). To test the degree to which this assumption might be violated, we tried a mark-recapture distance sampling (MRDS) experiment. MRDS requires two vehicle observer teams to closely follow each other on the same transect, although with the observers in the following vehicle (secondary observers) positioned so that they are higher than the primary observers, and therefore see further. The secondary observers are thus able to potentially observe animals before responsive movement occurs, and also better able to estimate group size. The secondary observers noted whether or not the primary observers saw each observation, thus facilitating identification of duplicate observations made by both the primary and secondary observers.

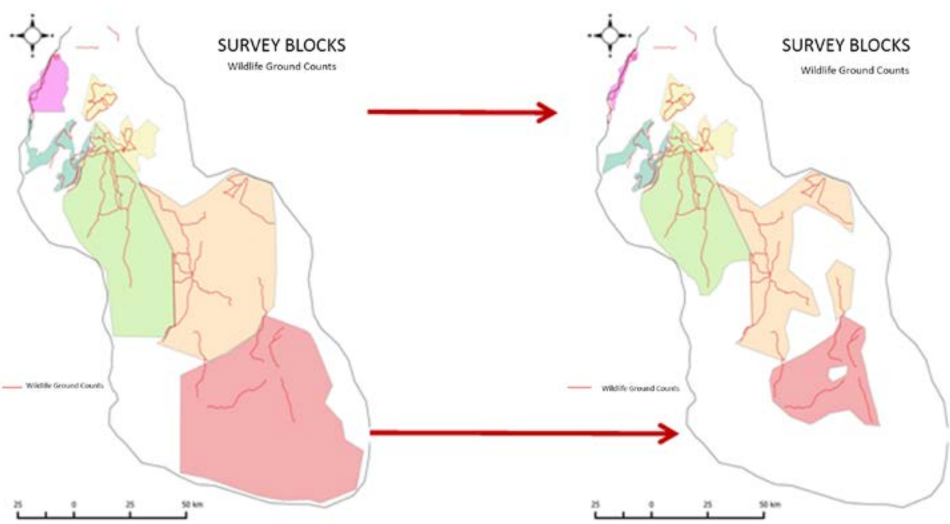

Figure 1:*All survey blocks within Tarangire (left) and areas of focus (right).*

Aerial census

The aerial census was conducted following the systematic reconnaissance flight (SRF) technique as described by Norton-Griffiths (Norton-Griffiths 1978), and a smaller area of total count (TC) in Lake Manyara National Park where transect flying is inappropriate due to the narrowness of the block and terrain (Norton-Griffiths 1978). Three aircrafts (5H-TPK, 5H-TPM and 5H-MPK) were flying at a target height of 350 ft. (~109m) above ground and a target ground speed of 180 km/h. SRF is a sample method, based on sampling narrow strips along transects (long flight lines), where the average density of each species in the samples is then multiplied by the total area to produce an estimate for the total survey area. The method depends on the samples being representative of the whole population – not that the animals themselves are evenly distributed, but that the samples are allocated without reference to the distribution of animals; in the case of SRF, the samples are allocated systematically according to a predefined map. Total counts rely on searching and enumerating all target species in a survey area. It is appropriate for a limited set of highly-visible species and small areas that can be counted in a single flight session.Normally only buffalo and elephant are counted in total counts (highly visible and aggregated species), but other species (impala size and larger) were also counted due to the small sample block size; however, it is likely that these smaller species were undercounted in the Manyara block.

Transects were spaced at 2.5km and 5km intervals with variable orientations due to the nature of the terrain, ecological gradient and aiming at maximizing the number of samples (Figure 2). Transects were a priori evenly subdivided into subunits between 2.1 and 2.5 km in length (typically around 40 seconds of flying time) and uploaded onto GPS units. Geo-referencing of aircraft on transect was determined by GPS (Garmin 60Csx or 296). An aerial total count method was used over the escarpment in the Lake Manyara National Park. The survey crew consisted of four individuals in each aircraft. The pilot navigated the aircraft following a survey plan that was loaded into the GPS prior to the flight. Front Seat Observer (FSO) was responsible for the inflight recording of transect metadata including the beginning and end points of each transect, the beginning and end time of each transect, flight height above ground using a radar or laser altimeter in each subunit, predominant vegetation, presence or absence of water and extent of burnt areas. The FSO also announced the subunit identification numbers to the rear seat observers. Left and right Rear Seat Observers (RSOs) counted and recorded on digital recorders all observations of animals and human activities sighted in each sub-unit. Photos were taken of large groups with more than ten individuals. The RSOs transcribed recorded data on to data-sheets after each flight session. Counting was confined within a sample area defined by streamers attached on the wing strut on each side of the aircraft with a target width of 150m on the ground. The geographical position of every subunit as called-out by the FSO was recorded together with its observations and subsequently transcribed on data sheets. For the total count area, a single session with two RSOs, FSO (recorder) and pilot was flown, counting all species above impala size, with the FSO marking all observations on a GPS and datasheet.

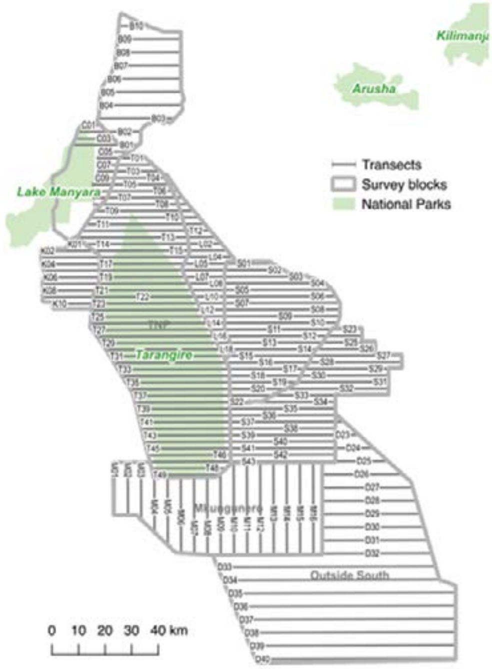

Figure 2: *Planned transects in the Tarangire-Manyara Ecosystem.*

A total area of 16,521km2was covered by 190 transects. On average, all aircraft flew at 339 ft. above ground at an average speed of 171 km/h. The transect strip width was maintained at 291m on average for the entire census zone.The majority of transects were flown in an east-west direction, although theMkungunero Block was flown north-south. The Lake Manyara National Park escarpment was flown as a total count due to the terrain being too difficult for SRF. One transect was omitted on the last day in the southern block as the aircraft exceeded its endurance; this has little effect on estimates.Collected data were analysed using Jolly's unequal sample size method 2 (Jolly, 1969; Norton- Griffith, 1978) to calculate the population estimates with a script in R.

RESULTS

During the analysis we found that there were signs of road avoidance and that this differed by species and survey block. For example, for zebra there was no sign of road avoidance in Tarangire NP (Figure 3a), but signs of it in Lake Natron (Figure 3b). For wildebeest and the other species road avoidance seemed to be less extreme. In cases where road avoidance was apparent, it was necessary to right-truncate some of the data to improve model fit when fitting the detection function.

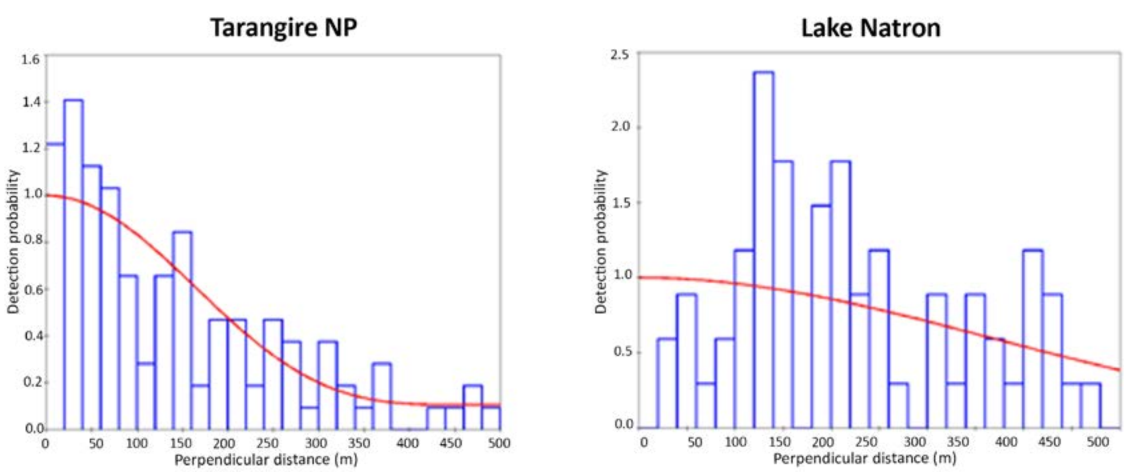

Figure 3: *Signs of road avoidance. 3 (a) No sign of road avoidance by Zebra in Tarangire NP and Figure 3 (b) indicates signs of it in Lake Natron for the same*

The results of the MRDS trial showed that the detectability assumption was only violated to a small degree introducing only a small amount of inaccuracy. Not surprisingly, impala groups were the least detectable on the line and even for this species the detectability on the line was higher than 91%. For the remaining focal species detectability ranged from over 94% to perfect detectability. MRDS involves a more-costly (2 separate survey teams) and more complex analysis and thus it was deemed preferable to using regular Distance sampling to monitor trends. MRDS also indicated that there were no severe assumption violations due to movement when using standard Distance sampling. Thus, in cases where there were fewer animals than expected on or near the road, this was not due to movement away from the observers, but due to general road avoidance, perhaps due to unsuitable habitat or disturbance from traffic on or near the road. In these cases, depending on the characteristics of the data for the particular species, we either fit a detection function with a wide shoulder or left truncated the data to eliminate potential inaccuracy due to road avoidance. A summary of ground count distance sampling density estimatefigures and the aerial count figures obtained for the six target species during the dry season of 2016 are presented below (Table 1).Results were similar for four of the six species, although there was a very large difference between counts of Impala derived from DS and aerial counts. Transects were spaced at 2.5km and 5km intervals with variable orientations due to the nature of the terrain, ecological gradient

Table 1: Dry season 2016 abundance estimates with standard error for six target species within the Tarangire ecosystem.

Animal Spp	Distance Sampling	Aerial Counts
Zebra	25,507 *(6,619)*	21,709 *(2,844)*
Wildebeest	**19,179** ***(5,794)***	**13,603** ***(3,381)***
Impala	53,539 *(10,065)*	5,721 *(687)*
Grant's Gazelle	**7,391** ***(2,106)***	**4,307** ***(712)***
Giraffe	2,500 *(542)*	3,904 *(507)*
Elephant	**6,164** ***(1,985)***	**7,882** ***(1,237)***

DISCUSSION

The results of the study revealthat ground and aerial counts produced figures within similar confidence limits for four of the six target animal species (Zebra, Wildebeest, Grant's gazelle and Elephant). For two other species, Impala and Giraffe, numbers were significantly different, although Giraffe numbers were only slightly higher in aerial counts than in ground counts. There is a considerable discrepancy between impala numbers derived from aerial counts and those obtained from ground counts. Aerial counts going back to the 1980's have consistently recorded between 4000 and 8000 individuals across the Tarangire ecosystem (TAWIRI 2016). The ground count figure,however, suggeststhat there are between 43,000 and 63,000 Impala in the ecosystem. It is highly likely that aerial surveys have been undercounting impala across the Tarangire ecosystem; Impala are relatively small antelopes, have brown backs that blend in well with vegetation, and, most importantly, they typically occur in areas of denser bushland or thicket.

All of these characteristics make them difficult to count from the air, and it is likely that many are being missed during aerial counts, particularly those living in areas of thicker bush, such as southern Tarangire NP, Lake Manyara NP, the Simanjiroplains and MakameWildlife Management Area. Grant's gazelle, which are similar in body shape and colour to Impala, might also be expected to be under-counted from the air. However, this species prefers dryer parts of the ecosystem and occurs predominantly in open grassland, and this habitat preference makes Grant's gazelle much easier to see and count from the air.

The results of this study suggest that ground counts using Distance Surveys might provide a cost effectivealternativeto counting animals using SRF aerial counts. Ground count surveys of the Tarangire ecosystem can be carried out for under $3000, which means that repeated ground counts could be carried out for the cost of a single aerial count. Changes in density, distribution, and abundance obtained from the road counts could, therefore, provide important wildlife trends over time. Optimally, aerial count data could be used to calibrate ground count data (Lobora, 2017). This method could be used where a) high quality aerial count data are available, and b) a ground count is conducted at similar time to an aerial count. Wildlife numbers extracted from aerial flight 2.5km sub-units would be matched with animal numbers recorded from road counts where they intersect with the aerial count flight path. The ratio of the two could then be used to determine a correction factor which would be used to adjust figures in subsequent ground counts carried out in different years during similar seasons. While this would synchronise ground count with aerial count data, the downside to this method is that any biases within the aerial count would be introduced into the ground count data. For bushland species such as Impala and Greater and Lesser kudu, where ground counts provide more accurate count data, calibration could potentially occur the other way round, with ground count data being used to correct aerial data.

With budgets for wildlife counts being limited, the use of ground counts to complement aerial counts across protected areas should be considered as a management tool, which would alert protected area managers to respond more rapidly to changes in wildlife populations and allow them to respond to potential threats more rapidly.

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THE IMPACT OF CLIMATE CHANGE ON PASTORALISM AND NATURE CONSERVATION: A CASE STUDY OF NGORONGORO DISTRICT

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ABSTRACT
This paper focused on "The Impact of Climate Change on Pastoralism and Nature Conservation: case study of Ngorongoro District. The findings from this study shows that, pastoralism represents one example of an area for investment in which the dual objectives of development and biodiversity conservation can be achieved recognizing the important role of pastoralism in cultures, traditions, livelihoods and the provision of ecosystem services. Periodic and prolonged droughts provoke livelihood shocks and pastoralists are forced to modify their accustomed way of living. Contemporary pastoralists are facing the challenges of sustaining their livestock for water and pasture due to climate change. The coping mechanism by pastoralism on climate change through transformation into agro-pastoralism in the Ngorongoro District, results into threatening of the existence of livestock-wildlife ecosystem. Despite having clear traditional rules and practices about forest protection by pastoralists in the Loliondo, forest cover change does persist following pastoralist starting engaging in agriculture. Land cover analysis revealed an increase in degraded forest areas in the last 15 years. The degradation of the forest has resulted, in drying of about 30 per cent of rivers and streams from the accustomed catchment of rivers that feeds the Serengeti ecosystem and Lake Natron Ramsar-Site. Pastoralists have a comparative advantage of benefit from tourist investment. This is because they are native inhabitant of northern part of Tanzania endowed with several tourism attractions including themselves. Ngorongoro district can do better in investing in tourism and produce substantial income necessary for their wellbeing. The rest is supposed to come from livestock, crop production and or mining revenues. The shift pastoralism from a sustainable to an unsustainable land use option, such as the conversion of pastoral lands to sedentary agriculture or the replacement of traditional livestock breeds with exotic stock, can cause the degradation of ecosystem services.

Key words: Agro-pastoralism, Climate change, Nature conservation, Ngorongoro, Pastoralism

INTRODUCTION
Pastoralism emerged in East Africa (Kenya, Tanzania and Uganda) around 4000 BC, as a culturally and linguistically diverse range of societies with differences in terms of the livestock species kept (small ruminants, cattle, camels) and the degree to which hunting and small-scale, rain-fed agriculture were practiced and relied upon, (Kirstine, 1997; Lankester & Davis, 2016). Generally pastoralism has immense potential for reducing poverty, generating economic

growth, managing the environment, promoting sustainable development, and building climate resilience, (Jotoafrika, 2011). Contemporary pastoralists are facing the challenges of sustaining their livestock for water and pasture due to climate change. According to Nassef *et al.,* (2009), Pastoral and agro-pastoral communities employ various coping strategies to deal with climate and non-climate stress. In some cases they are being forced be transformed from pastoralists to agro-pastoralists.

Wildlife is present throughout many pastoral areas and often also depends on the natural resources, which pastoralists need to support their livestock, (Kijazi, et al., 1997; Nassef *et al.,* 2009). Nelson (2009) urge that, Pastoralists and wildlife remain to co-exist in grasslands ecosystems, with pastoralists devising few significant negative, and in certain cases positive, effects on wildlife masses and diversity. The Secretariat of the Convention on Biological Diversity, (2010) urge that Pastoralism represents one example of an area for investment in which the dual objectives of development and biodiversity conservation can be achieved recognizing the important role of pastoralism in cultures, traditions, livelihoods and the provision of ecosystem services. The author think that "shift pastoralism from a sustainable to an unsustainable land use option, such as the conversion of pastoral lands to sedentary agriculture or the replacement of traditional livestock breeds with exotic stock, can cause the degradation of ecosystem services."

Study by Sirima, (2015), noted, Despite having clear traditional rules and practices about forest protection in the Loliondo forest, forest cover change does persist following pastoralist starting engaging in agriculture. She noted that, Land cover analysis revealed an increase in degraded forest areas in the last 15 years. The degradation of the forest has resulted, for example, in drying of about 30 per cent of rivers and streams. Given that forest in the Loliondo is a catchment forest and the core for greater Serengeti ecosystem, if the rate of cover change increases, downstream areas such as Serengeti National Park and Lake Natron will be heavily impacted.

Effects of climate Change on Pastoralism

African pastoralists have, over many years, developed a range of diverse coping strategies to survive in the harsh dry lands environment – strategies which in today's discussions on climate change have been baptized Adaptation and Mitigation Strategies. Periodic and prolonged droughts provoke livelihood shocks and major pastoralist migrations as they look out for employment or any other livelihood survival or resources to support their families, (Simel, 2009).

In the past 50 years, pastoralists in East Africa have become increasingly reliant on agricultural products as well as participation in farming. The proliferation of agriculture has been caused, in part, by a growing preference for agricultural foods as well as the decline of livestock numbers relative to humans but also reflects state biases in agricultural development. A reduction in the livestock per capita ratio, declining milk yields in the dry season, and an overall increase in food insecurity following drought or outbreaks of livestock disease have also contributed to this change, (Lankester

& Davis, 2016). However TAWIRI (2016) noted that increasing livestock affects the livelihoods of pastoral communities as the herds exceed carrying capacity of the land and the livestock become more susceptible to climate shifts and drought. For this case, even in years where the prevailed drought is at magnitude that previously didn't cause much damage to pastoral livestock, but due to overstocking, occurrence of mild drought it become of threat. For long period, pastoral societies, cattle, have been making up the majority of livestock biomass (Nelson, 2009). However, in the recent years pastoralism are shifting from large to small stock, which are altering the landscape substantially characterized by severe overgrazing while converting large tracts of pasture into bare land, leading to bush encroachment and spreading of invasive plants, thus reducing the overall grazing carrying capacity.

According to Ngorongoro District Council (NDC), (2009), the district has been facing recurrence drought that has negatively affected pastoralists. In 2003/2004 the death due to drought was 37% sheep and goats and 31% cattle. In 2004/2005, there were 36% death of goats, 41% sheep and 33% cattle (Table 1).

Table 1: Livestock death due to drought 2003/2004 and 2004/2005

Year	Death Percentage		
	Cattle	Sheep	Goats
2003/2004	31%	w37%	37%
2004/2005	33%	41%	36%

Data from these two years indicates that small stocks (sheep and goats) suffered a lot compared to cattle. It is now becoming common for most pastoral societies to supplement cattle with concentrates given to the animal at the morning before going for grazing and at the evening before night rest. This situation contributes to rapid increase of cost of grains should drought occurs.

According to NDC (2009), the death of livestock during drought might have been accelerated by other factors such as prevalence of chronic diseases like CBPP and Trypanasomiasis during that time. The report indicated that pastoralists sold there cattle at the lowest price that have never experienced ranging from TZS 5,000 per cattle to 50,000 while one cockerel were sold at 15,000 at Ololosokwan at the same time. It is obvious that someone was able to purchase 3 adult cattle after selling one poultry (cockerel).

During the year 2009 drought period, about 27,685 were sold to people from Mara region and some of pastoralists sent their livestock to Mara region as a means serving some of them. The death of cattle from 2009 drought was estimated at 141,120 (29.4%) of 480,000 cattle in the district. The distribution of cattle death from 2009 drought is elaborated in the table 2.

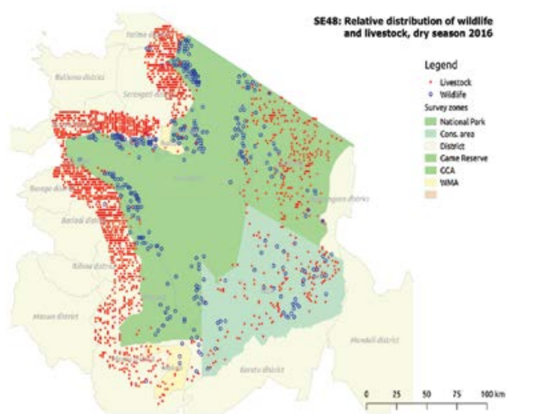

***Figure 1:** Livestock wildlife distribution around SNP, Source: TAWIRI (2016)*

Table 2: Livestock death due to drought in 2009

Ward	Number of Cattle	cattle died	% of death
Ololosokwan	22,000	12,232	55.6%
Soitsambu	56,214	21,024	37.4%
Masusu/ Pinyiny	11,049	5,679	51.4%
Engaresero	16,422	7,801	47.5%
Malambo	39,505	22,478	56.9%
Digodigo	13,437	538	4%
Oloipiri	18,184	5,390	29.6%
Arash	57,858	21,349	36.9%
Loliondo (Orkiu)	720	94	13%
Sakala	6,490	454	7%
Endulen	45,025	1,351	3%
Olbalbal	23,050	1,614	7%
Osinoni	3,476	455	13.1%
Kakesio	5,234	1,492	28.5%
Enguserosambu	18,701	7,050	37.7%
Oldonyowas (hamlet)	3,825	1,572	41.1%
Total	341,190	110,573	32.4%

Source: NDC (2009)

According to NDC (2017), the drought that occurred in late 2016 and early 2017 was estimated to wipe out 57,448 cattle, 24,186 goat and 41,882 sheep. According to TAWIRI (2016), during September 2016 Ngorongoro District was estimated to have 331,881 cattle and 488,546 sheep and goats. Based on TAWIRI (2016), aerial survey data and death of cattle as per NDC (2016), about 17.3% of cattle died during 2016 drought. The value of livestock decreased as low as TZS 30,000 per mature cattle while the value of food items such as maize increased from TZS 40,000/= per bag (90kgs) to as high as TZS 150,000/= per bag (90Kgs). This situation terrified pastoralists to the point that some of them started asking themselves if their Almighty God who they relied on has changed! The aerial pictures taken by TAWIRI (2016) indicated relative less densely distribution of livestock in Ngorongoro District when compared to distribution of livestock nearby Serengeti National Park (SNP) during the survey period (Figure 1).

Climate Hazards on pastoralists and coping Strategies

According Ngorongoro Resilient Assessment Report (2014), the climate hazard timeline identifies climate related hazards that have affected livelihoods (Table 3). These can include diseases, volcanic eruptions, or any other hazards perceived to impact livelihoods. Identifying coping strategies can be helpful in understanding the unplanned responses to climate hazards and their impact on the local environment.

Often, coping strategies undermine both themselves and the long-term sustainability of livelihood strategies. Coping strategies that have proved effective repeatedly may point to resilience building opportunities that are already being utilized by the community and could be scaled up.

The majority of rural African dry lands are inhabited by livestock keepers are either pastoralists or farmers who combine rain fed agriculture with pastoralism, (Kirstine, 1997). The impacts of changes in land tenure, conservation and land fragmentation, keeping livestock in the traditional pastoralist manner in East Africa has, in recent decades, become increasingly difficult, (Lankester & Davis 2016). The author noted that, Modern economic demands require pastoralist households to have access to cash to pay for health care, education and food, increasing the need for livelihood diversification to generate income.

Table 3: Climate Change Timeline in Loliondo and Sale Divisions, Ngorongoro District

Hazard	Location/ Year	Characteristics
Drought	Sale: 1994, 1996, 2000, 2005, 2009, 2013 Loliondo: 1994, 2001, 2003,2005, 2009, 2012, 2013	♦ Large scale movement to other divisions in search of pasture ♦ Death of livestock from pasture/water shortage ♦ Children leave school to search for or move closer to water sources ♦ Failure of harvests leading to famine – dependence on government food aid ♦ Occasional influx of pastoralists from Kenya in search of pasture – occasionally bringing diseases from Kenya ♦ Spread of livestock disease (Foot and Mouth Disease, East Coast Fever)
Heavy Rains and Flooding	Sale: 1998 Loliondo: 1998	♦ Spread of human diseases, particularly Malaria as the rainfall progresses. ♦ Spread of livestock diseases – Malignant Catarh Fever ♦ Destruction of houses and public infrastructures (roads, school buildings, bridges, i.e. Pololet) ♦ Destruction of harvests in lowland areas (highland areas benefit significantly) ♦ Caterpillars attack crops and pasture ♦ Growth of pasture – benefits to livestock that survive initial rains
Unseasonal Rainfall	Loliondo: 2014	♦ Causes unusual wildlife movements leading to raids on crops, grazing by human settlements and fatalities caused by elephants
Strong Winds	Loliondo : 2006	♦ Damage to houses and public infrastructure ♦ Wildlife attack crops

Source: Ngorongoro Resilient Assessment Report (2014).

From wage labour in cities, to involvement in gemstone mining and selling of beadwork and livestock products, these shifts can be seen as coping strategies to protect households from having to sell livestock. One livelihood change that is steadily increasing, particularly in critical buffer zone areas in Kenya and Tanzania, and that has the potential to devastate pastoralism and wildlife, is the conversion of lands for cultivation.

Pastoralism and Nature Conservation under climate change

Some years ago, the war against environment was believed to go well, Thomson, (2011) but the recent studies contradict it. The author noted that, "By 200 years ago, humans, our pets and our livestock had increased from 0.1% to 10-12% of the mass of the mammals of the earth; Now, we, our pets and our livestock make up 96% – 98% of the mass of the mammals of the earth. The poor old elephants and rhinos and all the rest of the mammals have gone from 99.9% to just 2 – 4% as indicated in the table 4. Usually natural resources in pastoral societies are owned communally. According to Hardin 1968, the communally owned of natural resources such as pasture in the Ngorongoro district provides room for few richer pastoralists to pour more livestock and threaten the conservation. Cash income from few elites in pastoral societies in the Ngorongoro district results in investments in housing and some shops, but most of all more income leads to a growing number of livestock (Slootweg, 2017).

Nelson (2009) urge that, "Pastoralists and wildlife continue to coexist in savannahs ecosystems, with pastoralists having few significant negative, and in some cases positive, impacts on wildlife densities and diversity." However, the study done by Swanson, (2007) indicated that "Increased livestock populations in the Ngorongoro system, showed reduction in wildlife and forage quality. In most cases pastoralists and small- holders, who depend on livestock for survival and income, have little access to emerging opportunities for growth, (Gerber, *et al.,* 2013). Maasai people in Ngorongoro district who are mostly livestock keepers have historically mainly depended on pastoral activities until about a decade ago when they started engaging more in agricultural

Table 4: Trends of Wildlife Population

Number of years	Situation
Ten thousand years ago	The mass, the weight, all of the humans on the earth, plus all our pets, plus all the livestock was 0.1% of the mass, the weight, of all the mammals on the earth, The rest of the mammals – elephants and giraffe and rhinos etc. – made up 99.9% of the mass of all the mammals on the earth.
By 200 years ago	Humans, our pets and our livestock had increased from 0.1% to 10-12% of the mass of the mammals of the earth
Now	We, our pets and our livestock make up 96% – 98% of the mass of the mammals of the earth. The poor old elephants and giraffe and rhinos and all the rest of the mammals have gone from 99.9% to just 2 – 4%.

Source: Modified from Thomson, (2011.)

activities (agro-pastoralists) partly due to climate change (Majory, 2014). The transformation of pastoralists into agro-pastoralists may have negative effects on nature conservation. It should be noted that most pastoralists are novices in agricultural practices. Usually, bad crop husbandry posses' threats on nature conservation.

Loliondo Forest which is found in Loliondo Division was once-heavily-forested area of Tanzania known as Loliondo Forest Catchment Reserve (LFCR), the forest resources are being lost due to encroachment for farming activities among other reasons (Majory, 2014). Study by Sirima, (2015), indicated that, the degradation of the forest in Loliondo following transformation of pastoralists into agro-pastoralists has resulted in drying of about 30 per cent of rivers and streams (Plate 1).

Keeping of small stocks such as sheep and goats by pastoral communities has become more popular. Pastoralists has maladapted keeping sheep and goats following there resilient to climate change when compared to large stock such as cattle. Although goats are browsers, sheep are good grazers. Keeping big flocks of sheep in the Ngorongoro district is know becoming threat to pastoralism. Apart form eating grasses as army worms, they graze up to ground level, damaging growing points of grasses. This situation has reduced pastures for livestock and wildlife at substantial level that threaten the existence of Ngorongoro Serengeti ecosystem. There is a debate among pastoralism in Ngorongoro district on whether lack of pasture in the area is purely due to climate change or keeping of big flocks of sheep are as detrimental to availability of pasture as occurrence of climate change. It should be noted that, the grazing habits of sheep, apart form constant damaging the growing points of grasses, they allow flourishing of non palatable plants to animals and invasive plants. These plants have reduced the carrying capacity of the available land in the district.

Provision of social services by the government to its people is among the key roles. In the past, pastoralists have been seen to be disadvantaged to access to education among other social services following their transhumance and lack of motives toward attending schools. In the recent years efforts has been devoted to ensure more pastoralists become educated and get employed to waged posts. Many tourists have been developed interest in visiting pastoralists and gain interest in supporting them through formulation and operation of Non Government Organization (NGOs) with annually donation of Billions Tanzania Shilling. Large portion of income earned by pastoralists from the operating NGOs, employment from the government and investors in the district such as hunting companies (OBC) and tourism companies (& Beyond, Thomson safaris etc.) are used in purchasing livestock. This is because livestock is the livelihood assets to pastoralists and as a sign of wealth and superiority. In turn, the more livestock is poured on the fixed land in the district, the more resources for animals are hampered.

Pastoralists who become relative well off develop interest on practicing polygamism resulting into increased number of Bomas (houses) and population. According to Swanson (2007), in pastoral communities

Plate 1: *Deforestation of Loliondo Forest for the cost of agro-pastoralism.*
Source: NARECO, 2014.

each man may have between two and five wives, each giving rise to approximately eight children. According to WWF (2014), many of the protected areas like that of Ngorongoro District were created where human population was low. In these areas pastoralism were possible due to availability of large area for grazing their livestock, (Nelson, 2009). For this case, uncontrolled increase of livestock in the district presents other hand for occurrence pronounced climate change while endangering the existence of the accustomed livestock wildlife ecosystem in the district.

The future of pastoralism

According to Simel, (2009), many people from mainstream society today, who make up the political elite and policy makers, see the pastoralists in Africa as the embodiment of a primitive society that is anti-change and anti-development. Porokwa, (2009) referred Hansard, December 30, 2005 that was recorded that:

"Mr Speaker, we must abandon altogether nomadic pastoralism which makes the whole country pastureland..The cattle are bonny and the pastoralists are sacks of skeletons. We cannot move forward with this type of pastoralism in the twenty first century."

Pastoralists are being faced with several challenges. For the case of pastoralists in the Ngorongoro district, climate change, present of overlapping laws on the same pastoral land (the 1959 GCA Act and 1999 Village Land Act) as well as uncontrolled livestock population increase jeopardize flourish of pastoralism and nature conservation in the district. Changing from pure pastoralists to agro-pastoral is evident in the district. The eating habits of pastoralists are changing from depending mainly on milk and meat to ugali and fish/poultry meat, situation that was aesthetically considered. Swanson (2007), noted that, in order to provide a 2,000 calorie per day diet for all pastoral residents in Ngorongoro, grain is used to supply 65% of their diet, p 34. It has been noted by TNRF (2011) although farming has been practiced in pastoral land in Loliondo since 1950s but was undertaken at area less than 5% because farming competes with grazing land. Usually foods of crop origins were used to supplement diets after milk, butter and meat. Despite of burning agricultural activities in the NCA, but, current about 39% of Ngorongoro District communities are engaged in agro-pastoralists mainly on maize production, (NBS, 2012).

The changes of pastoralists into agro-pastoralists due to climate change following death of livestock following lack of water and pasture. The Government and stakeholders are devoting more efforts to improve agriculture and development of infrastructures such as schools, roads and hospitals has encouraged sedentary life among pastoralists that eventually contributed to the transformation of pastoralists into agro-pastoralists. The pronounced pace for engaging into crop production by Loliondo pastoral communities has lead to shift from transhumance livestock keeping to sedentary following diminishing of grazing land due to implementation of new policies in land management and Game Control administration in the Loliondo division. Areas adjacent to Serengeti National Park (SNP) have been released to Ottelo Business Cooperation (OBC), a game hunting company and assorted tourism companies. For about two decades, conflicts has arouse toward eviction of the OBC from the area by the Loliondo community. Currently the government has proposed establishment of new GCA encompassing 1500 square kilometers adjacent to SNP from villages bordering SNP in Loliondo and Sale division. The areas adjacent to SNP have been used by pastoralists for grazing their livestock during dry period, most importantly during drought.

The multiple land use diminished pastoral pastureland and has contributed to the transformation into agro-pastoralists in the district. Opening of new farm is accompanied with charcoal production that accelerates deforestation. The drying up of water sources in areas where agro-pastoralists is evident brought several questions toward conservation. It has been noted by Slootweg, (2017) that due to Ngorongoro district is governed by NCAA regulations at NCA, GCA regulations at Loliondo and Sale division and Lake Natron Ramsar-Site treaty guidelines, pastoralism. He noted that the district is threatened by predators, and rangeland is reserved for wildebeest, zebra and antelope, which gives a thrill to the Safari Experience of the 1 million tourists who come to visit the area every year; the local population sees its livelihood disappear.

The increasing of drought and human exposure has somewhat increased the possibilities of Maasai communities in Ngorongoro to access and practice other life forms than pastoralism (Masao *et al.* 2015). Their transformations into agro-pastoralists jeopardize conservation efforts that have been accrued for the past years. Pastoralists have a comparative advantage of benefit from tourist investment. This is because they are native inhabitant of northern part of Tanzania endowed with several tourism attractions including themselves. It has been noted by Slootweg (2017), “Ngorongoro District can do better in investing in tourism. In the district, there are number of inhabitants who has big number of livestock that can be sold and get funds that can be used in investing in tourism industry. Using assumption, he indicated that, When 666 persons invest about $10,000 in the construction of a room for tourists, and when

25% of the constructed accommodation is occupied over the year, we will have in 10 year 6,667 rooms, rented out at 60$ per person including meals this would result in yearly earnings of 72 Million US$ by 2026. This would contribute for 22% of the target of 333 million gross incomes for 264,000 people living in Ngorongoro District by 2026. When we assume a multiplier effect between 0.87 and 1.83 the total effect on the economy would be between $135 and $204 million in 2026, which would be good for a contribution between 41% and 61% to the target middle-income status of an average $1,260 per person per year. The rest is supposed to come from livestock and meat processing, crop production and food processing or mining revenues, p 17."

Livestock keeping by pastoralists will require reduction of number of stocks kept in order to perform better. Pastureland has to be free from unpalatable plants and invasive weeds. Reliable source of water have to be well thought off, developed and managed particularly in grazing land. Livestock have to continue share the same ecosystem with wild animals. However, well-developed motivation schemes need to develop that provides mutual benefits by both pastoralists and conservation of the Ngorongoro Serengeti Ecosystem. Unless otherwise, nomadic pastoralism is a viable utilization system but will continue to be so in the future, as long as the following elements are ensured: maintenance of mobility to allow optimal use of the heterogeneous environment, secured access and rights to key grazing and water resources, and flexible responses to uncertain events, Kirstine, (1997).

CONCLUSION

This study can concluded that contemporary pastoralists are facing the challenges of sustaining their livestock for water and pasture due to climate change. The coping mechanism by pastoralism on climate change through transformation into agro-pastoralism in the Ngorongoro District, results into threatening of the existence of livestock-wildlife ecosystem. Despite having clear traditional rules and practices about forest protection by pastoralists in the Loliondo, forest cover change does persist following pastoralist starting engaging in agriculture. Land cover analysis revealed an increase in degraded forest areas in the last 15 years. The degradation of the forest has resulted, in drying of about 30 per cent of rivers and streams from the accustomed catchment of rivers that feeds the Serengeti ecosystem and Lake Natron Ramsar-Site.

Pastoralists have a comparative advantage of benefit from tourist investment. This is because they are native inhabitant of northern part of Tanzania endowed with several tourism attractions including themselves. Ngorongoro district can do better in investing in tourism. In the district, there are number of inhabitants who have big number of livestock that can be sold and get funds that can be used in investing in tourism industry. They will be able to raise income between $135 and $204 million in 2026, which would be good for a contribution between 41% and 61% to the target middle-income status of an average $1,260 per person per year. The rest is supposed to come from livestock and meat processing, crop production and food processing or mining revenues. Livestock keeping by pastoralists will require reduction of number of stocks kept in order to perform better. Pastureland has to be free from unpalatable plants and invasive weeds. Reliable source of water have to be well thought off, developed and managed particularly in grazing land.

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DAILY PROGRAMME: DAILY PROGRAMME 5TH -8TH DECEMBER 2017

Tuesday 05th December 2017

Time	Activity	Location/Venue	Responsible
9:00-16:00	Pre-conference-symposium on Spirochete Infections *in* Wildlife and Humans	Duluti Conference Hall-AICC	Julius Keyyu & Organizing Committee
15:00 – 18:30	Delegates/participants arriving & Registration	AICC - Conference registration desk	Organizing Committee

DAY ONE WEDNESDAY 06th DECEMBER 2017

EVENTS/PRESENTATIONS: SIMBA CONFERENCE HALL				
S/N	**Time**	**Event/Paper**	**Responsible**	**Remarks**
(i)	07:30 – 08:30	Registration & Logistics	Organizing Committee	
(ii)	08:30 – 08:40	House keeping	MC	
(iii)	08:40 -08:50	Welcome remarks	Director General- TAWIRI	MC
(iv)	08:50-9:00	Introductory Speech	Chairperson-TAWIRI Board	MC
(v)	09:00-09:40	Opening Speech	Guest of Honor-Minister - MNRT	MC
	09:40-10:00	Group Photo	Organizing Committee (OC)	**MC**
	10:01 – 10:30	**TEA/COFFEE BREAK**	**All**	**MC**
DAY ONE: MORNING PLENARY SESSION- KEYNOTE PAPER PRESENTATION No. 1-				
S/N	**Time**	**Event/Paper**	**Presenter**	
1	10:30 – 11:10	Establishing mechanisms of ungulate population declines in human-dominated pastoral lands of East Africa	Joseph O. Ogutu	Fred Manongi
DAY ONE: MORNING PARALLEL SESSION 1: SIMBA CONFERENCE HALLSUB-THEME: HUMAN-WILDLIFE INTERACTION				
S/N	**Time**	**Paper**	**Presenter**	
2	11:15-11:30	Human-lion conflict in northern Tanzania: patterns, local perceptions and efficacy of methods to prevent nocturnal and diurnal livestock predation by lions	Christian Kiffner *et al*	Grant Hopcraft

3	11:30-11:45	The future of protected areas in developing countries in the face of human population growth: the need for making ecosystem services more distance-independent	Han Olff *et al*	
4	11:45-12:00	Evaluating conservation and development impacts of Serengeti National Park	Dennis Rentsch *et al*	
5	12:00-12:15	Do hunting bans precipitating illegal hunting and exacerbating wildlife declines -a case study	Kina Murphy *et al*	
6	12:15-12:30	Mapping & understanding the risk of illegal activity in the western Serengeti	Kristen Denninger Snyder *et al*	
7	12:30-12:45	Lion trophy hunting in the United Republic of Tanzania – a retrospective analysis of quota, offtake, and age of harvested lions between 2011 and 2017	Ligate Fredrick Ambwene *et al*	
8	12:45-13:00	Livestock, pastoralism and improving income while protecting biodiversity in Ngorongoro District	Sef Slootweg *et al*	
	13:00– 14:00	**LUNCH**	All	OC/MC
DAY ONE: AFTERNOON PLENARY SESSION 2: KEYNOTE PAPER PRESENTATION No. 2- SIMBA CONFERENCE HALL				
S/N	**Time**	**Paper**	**Presenter**	
9	14:00-14:40	Livestock incursions and farming as drivers of Human-Wildlife Conflicts in Tanzania: an overview	James Wakibara	Tim

DAY ONE: AFTERNOON PARALLEL SESSION 1: SIMBA CONFERENCE HALL SUB-THEME: HUMAN-WILDLIFE INTERACTION				
10	14:45-15:00	Using interview based occupancy analysis to improve our understanding of carnivore attacks on livestock	Leejiah Dorward *et al*	William
11	15:00-15:15	Spatial enabled mobile application for Community Based Natural Resource Management (CBNRM)	L.R. Mathew	
12	15:15-15:30	Wildlife crime promoted by weak governance	Juma Salum *et al*	
13	15:30-15:45	Large carnivores management options that may address current intolerances amongst Maasai community living in the Ngorongoro Conservation Area, Tanzania	Emmanuel Masenga *et al*	
14	15:45-16:00	How WMAs affects human-wildlife Conflicts?	Lund JF *et al*	
	16:00-16:30	**Health break**		
15	16:30-16:45	The use of precautionary principle in addressing climate change in Tanzania	Montanus C.Milanzi *et al*	
16	16:45-17:00	The impacts of the climate change on Tanzanian's livestock. Its implication on biodiversity conservation/ wildlife conservation.	Chediel Mrisha *et al*	
17	17:00-17:30	When monitoring matters: 10 years (2007-2016) of Udzungwa Ecological Monitoring Centre	Francesco Rovero *et al*	Special paper

DAY ONE: MORNING PARALLEL SESSION 2: TAUSI CONFERENCE HALL **SUB-THEME: HUMAN-WILDLIFE INTERACTION**				
S/N	**Time**	**Event/Paper**	**Presenter**	**Chairperson**
18	11:15-11:30	Population trends and prospects of Black Rhino in Tanzania	Kakengi *et al*	Charles Foley
19	11:30-11:45	Assessing the feasibility of establishing an incentive-based program to promote human-lion coexistence in the Ngorongoro Conservation Area	Adam Pekor *et al*	
20	11:45-12:00	Spotted-necked otters: the good, the bad, the lore, and the future for this little known African species	Janice (Jan) Reed-Smith *et al*	
21	12:00-12:15	Trophy hunting industry in Africa: a review analysis of its impacts on biodiversity conservation	Shilereyo, M.T. *et al*	
22	12:15-12:30	Theoretical perspectives on why illegal bushmeat Hunting is still persisting in Western Serengeti	Asanterabi Lowassa *et al*	
23	12:30-12:45	Wildlife roadkill abundance and disappearance rate on Karatu-Arusha highway in northern Tanzania	Taylor Phillips Gladys Ngumbi *et al*	
24	12:45-13:00	Developing community-based initiatives to ease human-wildlife conflicts in the Ruaha landscape	A. Constance *et al*	
25	13:00-13:15	The impact of 'visitors' single entry' system to local communities living adjacent protected areas; a case study of Robanda village in western Serengeti, Tanzania.	Moses T. Kyando *et al*	

	13:00 – 14:00	**LUNCH**	
	14:00-14:40	**PLENARY PRESENTATION IN SIMBA HALL**	James Wakibara

DAY ONE: AFTERNOON PARALLEL SESSION 2 : TAUSI CONFERENCE HALL **SUB-THEME: HUMAN-WILDLIFE INTERACTION**				
26	14:45-15:00	Assessing the anti-predator behaviours of cattle in the Tarangire-Manyara ecosystem	Jacalyn Mara Beck *et al*	Anna Czupryna
27	15:00-15:15	Impacts of wild animals to livestock; a case study of Ngorongoro District	Christian Cyril Rimoy *et al*	
28	15:15-15:30	Hunting as a major disturbance of wild mammals in the Ruaha-Rungwa ecosystem.	Kwaslema Malle Hariohay *et al*	
29	15:30-15:45	Drivers for livestock grazing pressure in protected areas of western Serengeti	Lameck Matungwa *et al*	
30	15:45-16:00	A comparative analysis of spatial and temporal variations in bushmeat consumption among school children in western Serengeti	Flora Manyama *et al*	
	16:00-16:30	**HEALTH BREAK**		
31	16:30-16:45	Who let the dogs out? Domestic dog ecology and ownership practices in villages west of Serengeti National Park	Anna Czupryna *et al*	Shadrack M. Kamenya
32	16:45-17:00	Human-Wildlife-Conflicts in Agricultural Landscapes: an integrated assessment approach	König, H. J, *et al*	
33	17:00-17:15	Human health risks of bushmeat consumption in three major ecosystems in Tanzania	Andimile Martin *et al*	
34	17:15-17:30	Potential contribution of nature-based tourism to conservation of African Wild dog in Loliondo Game Controlled Area-Serengeti Ecosystem, Tanzania	Bajuta, E. *et al.*	
END OF DAY ONE				
18:30 - 20:30: EVENING SCIENTIFIC GATHERING : MOUNT MERU HOTEL				

DAY TWO: THURSDAY 07th DECEMBER 2017

PAPERS, SEMINARS AND SYMPOSIUM PRESENTATIONS

PAPER PRESENTATIONS				
SUB-THEME: WILDLIFE ECOLOGY AND ECOLOGICAL INTERACTIONS				
DAY TWO: MORNING PLENARY SESSION- KEY NOTE PAPER PRESENTATION No. 3 **SIMBA CONFERENCE HALL**				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
35	8:30-9:10	The future of conservation: lessons from the past and the need for rewilding of ecosystems	Anthony R.E. Sinclair	Julius Keyyu
DAY TWO: MORNING PARALLEL SESSION 3: SIMBA CONFERENCE HALL				
36	9:15-9:30	The first complete assessment of the population, demography and distribution of the Zanzibar red colobus, *Piliocolobus kirkii*.	Tim R.B. Davenport *et al*	Julius Nyahongo
37	9:15-9:30	Lion abundance and spatial variation in density in Serengeti National Park	Jerrold L. Belant *et al*	
38	9:30-9:45	Ecological and demographic monitoring of elephants in Ruaha National Park	Josephine Smit *et al*	
39	9:45-10:00	Mammal and bird diversity in relation to land use and utilization in Serengeti	Bård Stokke *et al*	
40	10:00-10:15	Importance of termite mounds and other nutrient hotspots for grazing ungulates in the Issa Valley ecosystem	Gabriel Mayengo *et al*	
41	10:15-10:30	Correlates of distribution and abundance change in Tanzanian birds	Colin M. Beale *et al*	
	10:30 – 11:00	**HEALTH BREAK**		
42	11:00-11:15	Butterfly species richness, abundance and distribution in the Kihansi Gorge forest of Morogoro Region in Tanzania	Devolent Mtui *et al*	Francesco Rovero
43	11:15-11:30	The impact of climate change on pastoralism and nature conservation: A case study of Ngorongoro District	Kabura J. Philip *et al*	
44	11:30-11:45	What suppresses buffalo population recovery in Masai Mara ecosystem, Kenya?	Gundula S. Bartzke *et al*	

45	11:45-12:00	Evidence that stable and significant populations of African vultures persist in southern Tanzania	Corinne Kendall *et al*	
46	12:00-12:15	The same but different: structural changes in megadiverse spider communities along an elevational gradient	Nikolaj Scharff *et al*	
47	12:15-12:30	Identifying connectivity and gene flow barriers of African Savannah Elephants (*Loxodonta africana*) between the Greater Serengeti Ecosystem and other Metapopulations in Northern Tanzania	George Gwaltu Lohay *et al*	
48	12:30-12:45	Human-baboon conflict around Lake Manyara National Park, Tanzania	Moses J Shimba *et al*	
49	12:45-13:00	The ecology and role of land use on diversity, relative abundance and distribution of small mammalian carnivores in Ruaha ecosystem, Tanzania	Alphonse Msigwa *et al*	
50	13:00-13:15	The integration of physiological condition into movement models: how do wildebeest balance reproduction, nutrition and migration?	Grant Hopcraft *et al*	
13:00/13:15-14:00		**LUNCH**		
DAY TWO: AFTERNOON PARALLEL SESSION 3: SIMBA CONFERENCE HALL WILDLIFE ECOLOGY AND ECOLOGICAL INTERACTIONS				
51	14:00-14:15	Female reproductive performance compared to changes in group size, and group divisions, in olive baboons of Gombe National Park, Tanzania.	Anthony Collins *et al*	
52	14:15-14:30	Modelling livestock movements and the impacts on transmission of the endemic zoonoses in northern Tanzania	Gemma Chaters	
53	14:30-14:45	Adaptation to environmental changes in the greater Serengeti area of north-western Tanzania	Claudia Capitan *et al*	
54	14:45–15:00	The Feeding Ecology of Eastern Black Rhinoceroses (*Diceros bicornis michaeli*) in southern Serengeti National Park, Tanzania	Ngoti *et al*	
55	15:00 -15:15	Dietary competition between wild Impala and domestic goat as revealed by DNA-metabarcoding	Ingrid Aase *et al*	

56	15:15-15:30	Faecal Glucocorticoids Metabolite response in giraffes (*Giraffa camelopardalis tippelskirchi*) in relation to protected area management objectives in Tanzania	Marealle, W. *et al*	Maurus Msuha
57	15:30-15:45	Local knowledge on the status and use of named mammals and bird species found in Serengeti, north-west of Tanzania.	V. G. Ndibalema *et al*	
58	15:45-16:00	Influence of land-use types on distribution of cavity-nesting birds on the southern slopes of Mount Kilimanjaro	Saleh S. Seif *et al*	
	15:30-16:00	**Poster Presentation-Display area**		
	16:00-16:30	**HEALTH BREAK**		
59	16-30-16:45	Monitoring wildlife across the Tarangire and west Kilimanjaro ecosystems.	Lobora A *et al*	Julius Keyyu
60	16:45-17:00	Home range utilization and habitat selection by African wild dogs (*Lycaon pictus*) in the Serengeti ecosystem, Tanzania	Masenga E. *et al*	
END OF DAY TWO				

DAY TWO: MORNING PARALLEL SESSION 4: PAPER PRESENTATIONS

TAUSI CONFERENCE HALL

SUB-THEME: WILDLIFE ECOLOGY AND ECOLOGICAL INTERACTIONS

S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
61	9:15-9:30	Conserving hyperendemic Udzungwa restricted amphibians	Elena Tonelli *et al*	Noel Mbisse
62	9:15-9:30	Spotted-necked otter latrine site selection at Rubondo Island National Park: characteristics, habitat model development and validation, and application for monitoring and viewing	Tom Serfass *et al*	
63	9:30-9:45	A decision support system to monitor and inform chimpanzee habitat management in Tanzania	L. Pintea *et al*	
64	9:45-10:00	Estimating lion occupancy and spotted hyena abundance in Maswa Game Reserve	Jerrold L. Belant *et al*	

65	1 0 : 0 0 - 10:15	Abundance, habitats and feeding behaviour of the Black and White Colobus monkeys (*Colobus guereza*) at Forest Training Insitute, Arumeru District.	Richard Giliba *et al*	
66	1 0 : 1 5 - 10:30	Sexual segregation but not as we know it: the influence of size and sex on feeding in yellow baboons	Amani Kitegile *et al*	
	10:30 -11:00	**HEALTH BREAK**		
67	11:00-11:15	Spatial-temporal distribution, abundance, diversity and mortality of birds along roads' network in the Serengeti ecosystem, Tanzania	Ally K. Nkwabi *et al*	Silvia Ceppi
68	11:15-11:30	Spatial-temporal monitoring of the world heritage sites using google earth engine: a case study of Mount Kilimanjaro	Cuthbert l. R. M. Mallya *et al*	
69	11:30-11:45	Preliminary assessment of the seasonal use of habitats in Mikumi National Park	Deusdedith B. Fidelis *et al*	
70	11:45-12:00	The effects of firewood collection on the spatial and temporal patterns of relative abundance of forest mammals in the Udzungwa mountains of Tanzania	Emanuel H. Martin *et al*	
711	12:00-12:15	Health and ecology of African buffalo (*Syncerus caffer*) in Ruaha National Park, Tanzania	Epaphras A. Muse *et al*	
72	12:15-12:30	Variation in bushmeat and fish prices along the gradient of distance from Greater Serengeti Mara Ecosystem boundary and Lake Victoria, Tanzania	J. W. Nyahongo *et al*	
73	12:30-12:45	Status and distribution of *Diospyros natalensis* in the proposed kihansi conservation area in Morogoro Region, Tanzania	Devolent Mtui *et al*	
74	12:45-13:00	Extra-pair paternity in two sympatric coucalsthat differ in sex-roles: certainty of paternity does not shape paternal roles	Ignas Safari	
	13:00-14:00	**LUNCH**		

DAY TWO: AFTERNOON PARALLEL SESSION 4: TAUSI CONFERENCE HALL SUB-THEME: WILDLIFE ECOLOGY AND ECOLOGICAL INTERACTIONS				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
75	14:00-14:15	Changes in the Serengeti wildebeest migration over time and implications for management	Thomas A. Morrison *et al*	Kjetil Bavengar
76	14:15-14:30	Snakes of Dodoma Municipality: preliminary results	Titus Lanoy *et al*	
77	14:30-14:45	Spatial patterns and the impact of poaching in the Serengeti	Alfan Rija *et al*	
78	14:45 – 15:00	Effect of public road proximity on ground-dwelling insect communities in Arusha National Park	Houssein S. Kimaro *et al*	
79	15:00-15:15	Speciation of bushmeat samples around Tanzania's protected areas reveals extensive mis-identification of wildlife species	Asteria Joseph *et al*	
80	15:15-15:30	Interactions between Maasai Cultures and Wildlife: The Killing of Birds during "Sipoliyokishu", a Pre-Moran Stage	Jason R. John & Tauta L. Mappi	
81	15:30-15:45	Using stable Isotopes to assess movement of livestock across Serengeti Ecosystem	Kabalika. Z *et al*	
	15:30-16:00	**Note: Poster presentations are going on - Display area**		
	16:00-16:30	**HEALTH BREAK**		
82	16-30-16:45	Genetic diversity of eastern black rhinoceros (D*iceros bicornis michaeli)* in Tanzania.	Ronald V. K.Mellya *et al*	Sascha Knauf
83	16:45-17:00	Breeding ecology of Kori Bustard *Ardeotis kori strunthiunculus* in the Serengeti National Park	Emmanuel Clamsen Mmassy	
84	17:00-17:15	The combined effect of drought and shade on acacia robusta and acacia tortilis seedling growth and resource allocation.	Deusdedith M. Rugemalila	
		Seminar Presentations Continues in Duruti Conference Hall		
END OF DAY TWO				

B. DAY TWO: SEMINAR/SYMPOSIUM PRESENTATIONS

DULUTI CONFERENCE HALL 07TH DEC.2017

SEMINAR/SYMPOSIUM 1: Linking biodiversity, ecosystem functions and services in the Great Serengeti-Mara Ecosystem (GSME) - drivers of change, causalities and sustainable management strategies (AfricanBioServices Project)

TIME: 9:15 -13:00: Chairpersons: Eivin Roskaft

S/N	Time	Title	Presenter
	9:15-9:20	A brief introduction of AfricanBioServices	Eivin Røskaft
85	9:20-9:35	AfricanBioServices Data Base	Peter Ranke *et al*
86	9:35-9:50	Poor water quality a health risk from water-borne diseases to communities in the Serengeti ecosystem, Tanzania	Fyumagwa *et al*
87	9:50-10:10	Home range utilization and habitat selection by African wild dogs (*Lycaon pictus)* in the Serengeti ecosystem, Tanzania (WP2)	Masenga *et al*
88	10:10-10:25	Sustainable construction and maintenance of gravel road in protected areas – the case of Serengeti National Park	Joseph Tarimo & James Odieck
	10:25-10:30	Discussion	
	10:30-11:00	**HEALTH BREAK**	
89	11:00-11:20	Quantifying household dependence on ecosystem service derived income and prevalence of illegal grazing in the Greater Serengeti-Mara Ecosystem (WP5)	Xi Jiao *et al*
90	11:20-11:40	A flexible Bayesian state-space modelling for population dynamics of wildlife and livestock populations (WP3)	Sabyasachi *et al*
91	11:40-12:00	Development beyond “Sustainable poverty”? Wildlife conservation and local economic development in Tanzania.	Teklehaymanot g. Weldemichel *et al*
92	12:00-12:20	A red rag to a savannah decomposer: controls of root litter decomposition inside and outside the serengeti national park	Stuart. W. Smith et al
93	12:20-12:40	The role of Community Facilitators and results determination	Benard Betty

	12:40-13:00	Discussions	Bente Graae
	13:00-14:00	**LUNCH**	

DAY TWO: SYMPOSIUM 2. WILDLIFE DISEASE ASSOCIATION-AFRICA AND MIDDLE EAST (WDA-AME) SECTION SYMPOSIUM AND ANNUAL MEETING

SYMPOSIUM THEME: THE ROLE OF WILDLIFE HEALTH PROFESSIONALS AND THE INCREASING TREND OF EMERGING AND RE-EMERGING DISEASES AT THE WILDLIFE-LIVESTOCK-HUMAN INTERFACE

DULUTI CONFERENCE HALL, 07TH DEC.2017

TIME: 14:00 -18:00: Chairpersons: Thomas Nyariki

S/N	Time	Title	Presenter
94	14:00-14:20	Skepticism can be useful: Is there really an increasing trend for emerging and re-emerging diseases at the Wildlife - Livestock Interface?	David A. Jessup
95	14:20-14:40	How can we best increase wildlife health professional capacity? A lens on East Africa.	Richard Kock
96	14:40-14:50	Past, current and future perspectives of One Health at the face of Global Health Challenges: Tackling Wildlife Zoonotic Diseases Perspective	Lawrence Mugisha
97	14:50: 15:00	The role of One Health in safeguarding wildlife health in Tanzania: Opportunities and challenges	Julius Keyyu *et al.*
98	15:00-15:10	Revisiting Brucellosis in the Greater Yellowstone area	David A. Jessup
99	15:10-15:20	A One-Health approach to Mountain Gorilla Conservation: Challenges and Opportunities for research, training and business	Benard Jasper Ssebide
100	15:20-15:30	A successful vaccine trial reveals an opportunity to control mMalignant Catarrhal Fever in cattle	Elizabeth Cook *et al*
101	15:30-15:40	Preliminary investigation of an outbreak of unknown disease following consumption of wild boar meat in western Ethiopia.	Jack Mortenson and Tegegne
102	15:50-16.00	Investigation of Malignant Catarrhal Fever in cattle comparing PCR and ELISA methods for diagnosis	S.A. Oronoet *al.*,
	16:00-16:30	**HEALTH BREAK**	
103	16:30-16:40	Haematological Values of Healthy and Sick Free-Ranging Lesser Flamingos *(Phoeniconaias Minor)* in Kenya.	Nyariki *et al.*

104	16:40-16:50	The African (cape) buffalo (*Syncerus caffer*) is a reservoir of important zoonotic diseases	Cook *et al.*,
105	16:50-17:00	Use of Long-Acting Neuroleptic Tranquilizers for Wood Bison (*Bison bison athabascae)* handling during health evaluations and transport	Jack Mortenson
106	17:00-17-10	Faecal Zoonotic Bacteria at the Wildlife-Livestock Interface from Geographic Areas Close to Natural Protected Areas from Uganda	Cabezon *et al.*
107	17:10-17:20	Evaluation of the implementation of One Health in Kenya: A case study of the Zoonotic Disease Unit	Kelvin Momanyi *et al.*
108	17:20-17:30	Manifestations of Capripox Disease in non-Domesticated Ruminants	Stephen Chege
109	17:30-18.00	General Discussion and Symposium closing	Chairman
	15:30-16:00	**Note: Poster presentations are going on - Display area**	

DAY TWO: POSTER PRESENTATIONS: 07TH DECEMBER 2017

TIME: 15:30 – 17:00

S/N	Title	Presenter (s)
110	Assessment of the agriculture policy towards adaptation of the climate change impacts in sub-Saharan African agriculture	Chediel Mrisha, *et al*
111	Estimating lion abundance using spatially-explicit capture-recapture models	Jerrold L. Belant *et al*
112	What controls the spread of *Gutenbergia cordiforlia* in the Serengeti ecosystem?	Evaline Munisi *et al*
113	Effect of altitude on woody vegetation along slopes of a volcanic, tropical mountain	Julius V. Lasway *et al*
114	Monitoring human-wildlife conflict in the western Serengeti	Kristen Denninger Snyder etl al
115	Comparison of spotlight and thermal imaging to detect lions and spotted hyenas	Jerrold L. Belant *et al*
116	Social-economic survey of the use of the edible wild orchids in Mpanda District	Angela Mwakatobe *et al*
117	How gender influences conservation intervention aimed to curb illegal bushmeat hunting in Serengeti: Case study of Community Conservation Bank	Asanterabi Lowassa *et al*

118	Track survey do not provide accurate lion density estimates in Serengeti National Park	Jerrold L. Belant *et al*
119	Spatial and temporal overlap of caracals (*Caracal caracal*) and servals (*Leptailurus serval*) in Serengeti National Park, Tanzania-	Stanslaus B. Mwampeta *et al*
120	Activities endangering tree species composition and Diversity at Nkoanenkole Catchment Forest Reserve in Arumeru District.	Kayombo *et al*
121	Visitor's experience and satisfaction: A case study on the status and capacity of visitor's facilities inside and adjacent Serengeti National Park**.**	Ntalwila, J. *et al*
122	Assessment of farmer's breeding decision for sustainable diary production in smallholder production systems using discrete choice experiment method	Chawala, *et al*
123	Temporal and spatial variation of broadcasted vocalizations does not reduce lion habituation	Jerrold L. Belant *et al*
124	Pastoralist herding efficiency in dealing with carnivore-livestock conflicts in the eastern Serengeti, Tanzania	Richard D. Lyamuya et
125	Delineating corridors for multiple wildlife species in the Tarangire-Manyara Ecosystem.	Riggio, J. *et al*
126	Detecting changes in Land use and land cover changes (2001-2016) in the Greater Ruaha and Kitulo-Kipengele Landscapes, Southern Tanzania	Kija, H. *et al*
127	The wildlife health bridge: education in wildlife health for biodiverse countries	Sainsbury AW *et al*
128	Enhancing Local Capacity in Bird Research and Raising Conservation Awareness in East Usambara Mountains	Jasson R. John *et al*
	A survey of human-elephant interactions around the Ruaha-Rungwa ecosystem	Josephine Smit *et al*
END OF DAY TWO		

DAY THREE: FRIDAY 08th DECEMBER 2017

PAPERS, SEMINARS AND SYMPOSIUM PRESENTATIONS

PAPER PRESENTATIONS				
SUB-THEME: WILDLIFE DISEASES AND ECOSYSTEM HEALTH				
DAY THREE: MORNING PLENARY SESSION: KEY NOTE PAPER PRESENTATION NO. 4, SIMBA CONFERENCE HALL *SUB-THEME: WILDLIFE DISEASES, ZOONOSES AND ECOSYSTEM HEALTH*				
S/N	**Time**	**Paper**	**Presenter**	
129	8:30-9:10	Zoonotic diseases at the human - domestic animal - wildlife interface in southern and eastern africa	Rudovick R. Kazwala	
DAY THREE: MORNING PARALLEL SESSION 5: SIMBA CONFERENCE HALL				
S/N	**Time**	**Event/Paper**	**Presenter**	**Chairperson**
130	9:15-9:30	A trial to assess the thermotolerance of an inactivated rabies vaccine	Lankester, F.J. *et al*	**Tiziana Lembo**
131	9:30-9:45	Anthrax outbreaks in protected areas: a warning for improved prevention, control and community awareness	Ernest Eblate *et al*	
132	9:45-10:00	Spirochete infections in wildlife and humans	Knauf, S. *et al*	
133	10:00-10:15	Shedding light on a neglected zoonosis: anthrax in the Ngorongoro Conservation Area	Olubunmi Rhoda Aminu *et al*	
134	10:15-10:30	Disease risk analysis for conservation translocation	Sainsbury A.W. *et al*	
	10:30-11:00	**HEALTH BREAK**		
135	11:00-11:15	Livestock movements as determinants of Foot-and-Mouth disease virus circulation in northern Tanzania	Ekwem, Divine *et al*	
136	11:15-11:30	Identifying reservoirs of human African trypanosomiasis in wilderness areas	Harriet Auty *et al*	
137	11:30-11:45	Improved understanding of Peste des Petits Ruminants (PPR) at the wildlife-livestock interface in Tanzania	Richard Kock *et al*	

138	11:45-12:00	Immobilization of free-ranging impala (Aepyceros melampus): experience from the Serengeti ecosystem, Tanzania	Justin S. Wanda *et al*	Fyumagwa
139	12:00-12:15	Human enteropathogens in wildlife: an operational indicator of ecosystem health	Teresa J. Sylvina *et al*	
140	12:15-12:30	Brucellosis in African buffalo (*Syncerus caffer*): a case report from the Ruaha ecosystem, Tanzania	Goodluck Paul_*et al*	
141	12:30-12:45	Genome profiling of multidrug resistance tuberculosis among patients in Tanzania	Bugwesa Z. Katale *et al*	
142	12:45-13:00	Long-term integrated health-monitoring in wild chimpanzees: the Gombe Ecohealth project.	Mwacha, D *et al*	
143	13:00-13:15	Insights on human behaviour and zoonotic disease risks in the bushmeat value chain in Tanzania's Ruaha ecosystem	Zikankuba Sijali *et al*	
144	13:15-13:30	Assessment of ecosystem health based on patterns of antimicrobial resistance of escherichiacoli isolates from human chimpanzee-contact groups and habituated wild chimpanzees (*Pantroglodytes*) at Mahale Mountains, Tanzania	Teresa J. Sylvina *et al*	
	13:00-14:00	**LUNCH**		

AFTERNOON: PARALLEL SESSION 6: SIMBA CONFERENCE HALL

SUB-THEME 5: WETLAND AND WATER RESOURCES MANAGEMENT

145	14:00-4:15	Tools for conducting rangeland and watershed restoration for herders and watershed professionals	Kina Murphy *et al*	
146	14:15-14:30	Macroinvertebrates as bioindicators of water quality in the Mkondoa River, Tanzania, in an agricultural area	Shimba MJ *et al*	
147	14:30-14:45	Estimating extreme dry spell risk in the ichkeul lake basin (northern Tunisia): a comparative analysis of annual maxima series with a gumbel distribution	Majid Mathlouthi et al	

148	14:45-15:00	Pattern of surface water availability for wildlife use in the Serengeti National Park	Kihwele, E. *et al*	Yustina Kiwango
149	15:00-15:15	Assessment of macroinvertebrates distribution and diversity in Kizinga and Mzinga rivers, Dar es salaam	Rehema Ulimboka *et al*	
150	15:15-15:30	Aquatic insects' diversity as bio-indicators: comparative study of three rivers in Moshi Municipality	Iddi Jamal Mshana *et al*	
151	15:30-15:45	Management practices guiding utilization of wetland resources in Nagulo Bahi village, Dodoma Region, Tanzania.	Kalista H. Peter *et al*	
152	15:45-16:00	Sensitivity of Africa's larger mammals to human disturbance	Jason Riggio	
	16:00-16:30	**HEALTH BREAK**		
	16:30-17:00	**RESEARCH-DIRECTORATES UP DATES**		
	17:00-17:20	**Closing Remarks – End of the 11th TAWIRI Scientific Conference**		
DAY THREE: MORNING PARALLEL SESSION 7: TAUSI CONFERENCE HALL **SUB-THEME: ETHNO BOTANY AND VEGETATION ECOLOGY**				
153	9:15-9:30	Ecology and growth dynamic of *Entandrophragma excelsum*. Africa's tallest tree species	Andreas Hemp *et al*	Inyasi Lejora
154	9:15-9:30	Investigation of traditional use of medicinal and food plants in northern Tanzania for their sustainable use	Julius Keyyu *et al*	
155	9:30-9:45	Landscape changes in the Albertine region in Uganda: role ofoil and gas exploration and development activities and implications for ecosystem services	Charlotte N. Jjunju *et al*	
156	9:45-10:00	Survey of plant species used against crop pests of post-harvest storage in Manyara region, Tanzania	Neduvoto P. Mollel *et al*	
157	10:00-10:15	Land cover change in pastoral and agricultural areas around the Serengeti ecosystem, 1984-2017	Anna B. Estes *et al*	

158	1 0 : 1 5 - 10:30	Grazing frequency, rainfall regime and reseeding activities in semi-arid rangeland management: a large-scale experiment on how grasses respond	Anna C. Treydte, *et al*	
	10:30-11:00	**HEALTH BREAK**		
159	11:00-11:15	Mapping rangeland degradation in Northern Tanzania: combining rapid ground surveys with remote sensing data	Rob Critchlow *et al*	
160	11:15-11:30	The effects of firewood collection on the spatial and temporal patterns of relative abundance of medium to large bodied forest mammals in the Udzungwa Mountains of Tanzania	Emanuel H. Martin *et al*	Julius Kibebe
161	11:30-11:45	Role of traditional ecological knowledge on forest conservation by Maasai community	Fred V. Ledidi *et al*	
162	11:45-12:00	A community-based approach to rangeland monitoring and management – examples of local implementation in the northern Tanzania rangelands	Charles Trout and Neovitus C. Sianga	
163	12:00-12:15	Effectiveness of different management areas in preventing forest loss in Tanzania	Isabel M.D. Rosa *et al*	
164	12:15-12:30	Human population growth squeezes greater Serengeti-Mara ecosystem	Veldhuis, M.P. et al	
165	12:30-12:45	Factors conditioning community implementation of environmental education for forest conservation in Tanzania: The case of Uluguru mountains, Morogoro Municipality	Joseph Manase *et al*	
166	12:45-13:00	Ruvuma landscape forest canopy density trends	Langen R. Mathew*et al*	
167	13:00-13:15	The key role of data-gathering to design evidence-based adaptation strategies: The case of rangelands in Arusha Region, northern Tanzania.	Silvia Ceppi *et al*	
	13:00-14:00	**LUNCH**		

AFTERNOON: PARALLEL SESSION 7: TAUSI CONFERENCE HALL **SUB-THEME: ETHNO BOTANY AND VEGETATION ECOLOGY**				
168	14:00-14:15	How does burning affect carbon pools in savanna ecosystems?	Bente Graae *et al*	Alphonse Mallya
169	14:15-14:30	The impact of illegal livestock grazing on woody plant structure and demography in the greater Serengeti Mara Ecosystem	Inger K. De Jonge *et al*	
170	14:30-14:45	Monitoring land cover and land use change (1975-2015) in the Serengeti ecosystem	Kija, H *et al*	
171	14:45-15:00	Developing standardized vegetation classification and mapping for improving wildlife conservation and land use planning in the Tarangire-Manyara ecosystem, Tanzania	John Vollmar *et al*	
172	15:00-15:15	Impact of agro-pastoralism on availability of herbaceous plants in western Serengeti	Pius Yoram Kavana *et al*	
173	15:15-15:30	Anthropogenic impacts on the behaviour and population dynamics of impala in relation to different land-use in the Serengeti ecosystem	Setsaas, T. *et al*	
174	15:30-15:45	Beekeeping practice; potential and challenges for honey and beeswax production in Simanjiro District, Manyara Region	Chediel Mrisha *et al*	
175	15:45-16:00	Queen Rearing experiments using Jenter technological equipment in Zuzu area, Dodoma Region.	Kipemba *et al*	
	16:00-16:30	**H EALTH BREAK**		
	16:30-17:00	**RESEARCH DIRECTORATE UPDATES: Julius Keyyu: - SIMBA HALL**		
	17:00-17:30	**CLOSING REMARKS- SIMBA CONFERENCE HALL**		
END OF DAY THREE – END OF THE 11TH TAWIRI SCIENTIFIC CONFERENCE **THANK YOU ALL FOR MAKING THIS EVENT ONE OF THE SUCCESS CONFERENCES**				

DAY THREE SEMINAR PRESENTATION: DULUTI CONFERENCE HALL

CHIMPANZEE CONSERVATION SYMPOSIUM

TIME: 9:15 – 13:00: Chairpersons: Edward Kohi

S/N	Time	Title	Presenter
176	9:15-9:30	The threats to wild chimpanzees from increasing agriculture and pastoralists, in western Tanzania	Shadrack M. Kamenya *et al*
177	9:30-9:45	An eco-friendly approach to tackle the accelerating decline of Tanzania's chimpanzees	Teresa J. Sylvina *et al*
178	9:45-10:00	Community-Based Conservation and Land-use Management in Gombe Masito Ugalla Ecosystem	Fadhili Mlacha *et al*
179	10:00-10:15	Feeding ecology of Mahale m-group chimpanzees: a case study on food preferences in relation to frequency and time spent foraging.	Simula Maijo *et al*
180	10:15-10-30	Traces and trends: a status update of extra-park chimpanzees of Tanzania's greater Mahale ecosystem	F. A. Stewart *et al*
	10:30-11:00	HEALTH BREAK	
181	11:00-11:20	Issa chimpanzees: lessons from one community for conservation strategies of an entire ecosystem	Alex Piel *et al*
182	11:20-11:40	Assessment of food competition in terms of quality and quantity between baboons and chimpanzees of Mahale Mountains National Park, Tanzania	Naftal Baraka *et al*
183	11:40-12:00	Demand for cooking energy as a challenge to Conservation: A case study in Greater Gombe Ecosystem	Fadhili Mlacha, *et al*
184	12:00-12:20	An update on the status of the chimpanzee population in Gombe National Park	Anne Pusey *et al*
185	12:20-12:40	Vegetation composition and population structure of two chimpanzees (*Pan troglodytes schweinfurthii*)	Sood Ndimuligo *et al*
186	12:40-13:00	Unhabituated chimpanzees (*Pan troglodytes*) in the highlands north of Gombe National Park, Tanzania	Deus C. Mjungu *et al*

	13:00 – 14:00	LUNCH	
	14:00-15:00	Discussion-Chimps symposium	Chairperson
	15:00-16:00	PRESENTATIONS GOING ON IN SIMBA AND TAUSI HALLS	
	16:00-16:30	H EALTH BREAK	
	16:30-17:00	Research Directorate updates: Keyyu	
	17:00-17:30	CLOSING REMARKS- SIMBA CONFERENCE HALL	
END OF DAY THREE – END OF THE 11TH TAWIRI SCIENTIFIC CONFERENCE THANK YOU ALL FOR MAKING THIS EVENT ONE OF THE SUCCESS CONFERENCES			

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