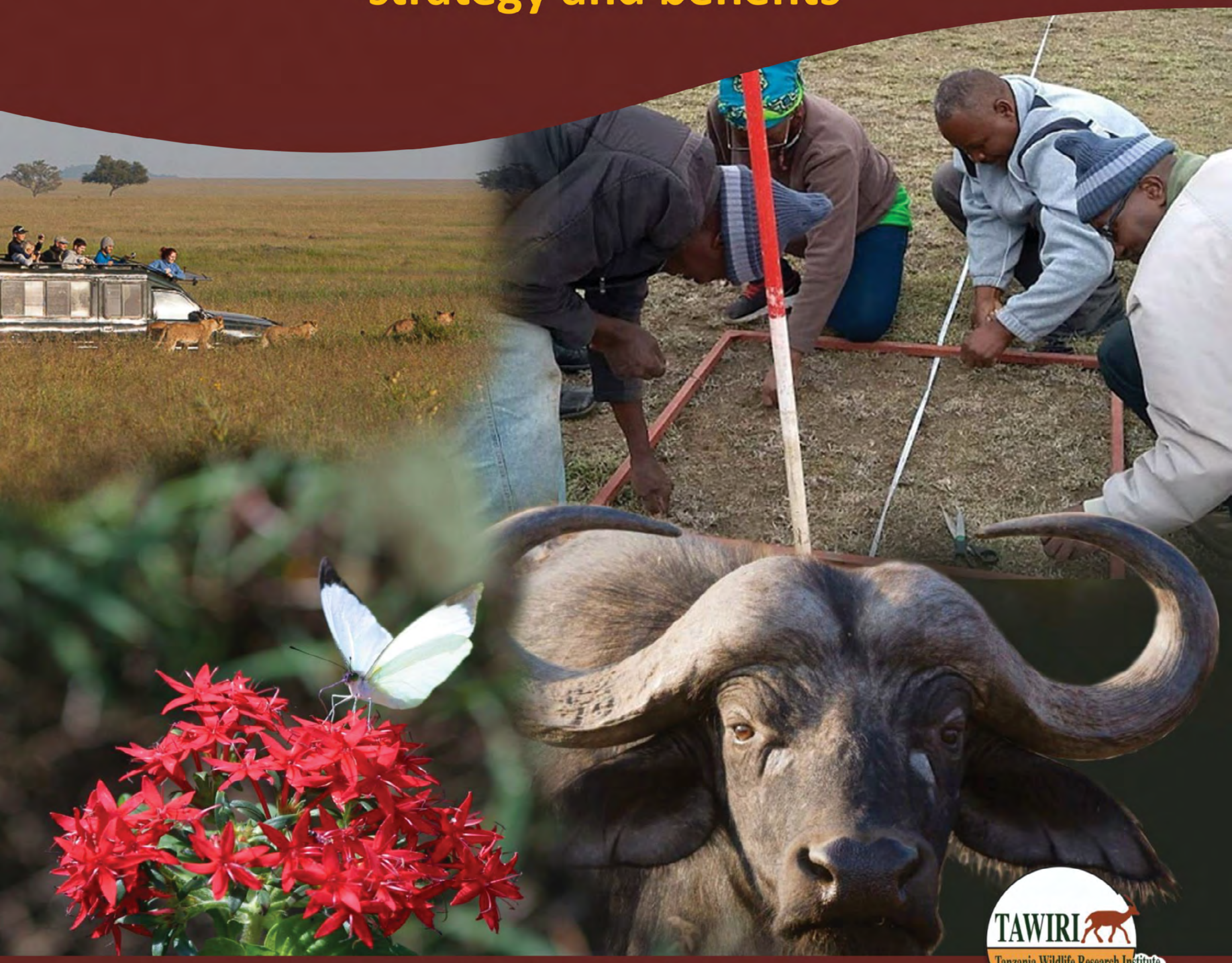
PROCEEDINGS OF THE 12TH TAWIRI SCIENTIFIC CONFERENCE

"A sustainable future for Tanzania's Biodiversity Conservation: The science behind priority, strategy and benefits "



4th - 6th December 2019
Arusha International Conference Centre,
Arusha Tanzania

TANZANIA WILDLIFE RESEARCH INSTITUTE
(TAWIRI)

PROCEEDINGS OF THE
TWELVETH TAWIRI SCIENTIFIC CONFERENCE,
4TH – 6TH DECEMBER 2019,
ARUSHA INTERNATIONAL CONFERENCE CENTRE,
TANZANIA

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CONFERENCE THEME

"A sustainable future for Tanzania's Biodiversity Conservation: The science behind priority, strategy and benefits "

MESSAGE FROM THE ORGANIZING COMMITTEE

The Tanzania Wildlife Research Institute (TAWIRI) scientific conferences are held biennially and brings aboard a wide range of stakeholders from within and outside the country. This year's meeting marks the 12th scientific conference under the Theme: "A sustainable future for Tanzania's biodiversity conservation: The science behind priority, strategy and benefit". The theme primarily aims at promoting the country's 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 related to the reigning theme to inform wildlife management authorities and the government at large. The engagement is hoped to help the government, management authorities and relevant stakeholders to periodically develop appropriate conservation actions to most of the challenges identified by researchers During the conference, there will be three broad keynote speeches to help keep the conference focused on the theme, 122 oral and 16 poster scientific presentations, one symposium, one workshop and four round table discussions. We hope that these presentations will address the current wildlife management challenges and propose solutions and mitigations measure especially on issues related to increasing population 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, resolutions generated from this conference is hoped not only to improve wildlife resources in the country but also foster trade offs between sustainable utilization and long-term conservation.

On behalf of the Management and staff of TAWIRI, the Organizing Committee of the 12th TAWIRI Scientific Conference is honored 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 Committee Members

Alex Lobora	Chairperson
Angela Mwakatobe	Vice Chairperson
Janemary Ntalwila	Secretary
Angela Hezekiah	Depute Secretary
Edward Kohi	Member
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SPEECH OF THE DIRECTOR GENERAL, DR. SIMON MDUMA, AT THE OFFICIAL OPENING OF THE 12TH TAWIRI SCIENTIFIC CONFERENCE AT ARUSHA INTERNATIONAL CONFERENCE CENTER DECEMBER 4TH , 2019

Honourable Minister, Dr. Hamis Kigwangalla (MP), Minister for Natural Resources and Tourism,
Permanent Secretary, MNRT,
Regional Commissioner – Arusha
Director of Wildlife, MNRT,
Conservation Commissioner, TAWA
Conservation Commissioner, TANAPA
Conservation Commissioner, NCAA
Mr. Bae, Yeon Jae, NIBR President,
Mr. David Thompson, Deputy Mission Director, USAID,
TAWIRI Management Team,
Distinguished Guests,
Conference Participants
Ladies and Gentlemen.

Good morning!

First and foremost, I thank God for making this day possible and I want to take this opportunity to thank you Honourable Minister in person, for dedicating your time for this important event, despite your very tight schedule. I would also like to thank Hon. Mrisho Gambo, the Arusha Regional Commissioner, for agreeing to be with us today in 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.

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 and conservationists in this gathering is one of the ways by which TAWIRI avails scientific information to stakeholders who are 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 “A sustainable future for Tanzania’s Biodiversity Conservation: The science behind priority, strategy and benefit”. This theme was selected in recognition of the current challenges facing wildlife conservation in the country.

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 to realize the future of our biodiversity richness and its role in supporting people's livelihoods and contributing towards the country's economic growth.

In this conference, we will have three keynote papers, one symposia, 4 round-table discussion and nine parallel sessions with a total of 138 in which 122 are oral and 16 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 12th 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 world at large.

Honourable Minister: TAWIRI is working in close collaboration with other researchers from within and outside the country in generating information that is important for conservation of wildlife resources. This is witnessed through a number of projects that were registered by the Institute during the financial year 2018/2019, where a total of 176 projects and 492 research scientists were registered and supervised. I am pleased to inform you that the number of Tanzanian wildlife research scientists has increased over the past six years from 125 scientists in the financial years 2012/2013 to 200 scientists in 2018/19.

Honourable Minister: On behalf of the Institutes's Management, allow me to express our very sincere thanks to organizations that made this conference possible namely Ministry of Natural Resource and Tourism (MNRT), Ngorongoro Conservation Area Authority (NCAA), Tanzania Wildlife Management Authority (TAWA) Grumeti Fund, Oikos, The Nature Conservancy (TNC), Frankfurt Zoological Society (FZS), United Asia Group (UAG), Jane Goodall Institute (JGI), Gadgetronix, NOMAD Trust, Friedkin Conservation Fund, Chemchem Association, USAID - Protect, Serengeti Wild Dog Project, Asilia Hotels Ltd, Miracle Experience and the Arusha International Conference Centre (AICC). These organizations are not only our recurrent supporters to this particular event but also support a wide array of conservation activities in various parts of the country. We sincerely thank these organizations and please keep up the spirit !

Honourable Minister: TAWIRI wishes to thank all delegates, most of them being researchers, academicians and conservationists who took their time to prepare presentations and attend this important gathering. In the midst of this delegation Honourable Minister, you can pose all kinds of questions to be addressed to support your Ministry particularly in the wildlife sector.

Honourable Minister: With these few words please allow me to welcome you to address this congregation and officially open the 12th TAWIRI Scientific Conference.

Honorable Minister, please welcome!

Thank you!

SPEECH OF THE MINISTER FOR NATURAL RESOURCES AND TOURISM HON DR. HAMIS KIGWANGALLA (MP) PRESENTED AT THE OFFICIAL OPENING OF THE 12TH TAWIRI SCIENTIFIC CONFERENCE,HELD AT THE ARUSHA INTERNATIONAL CONFERENCE CENTRE (AICC), ARUSHA ON DECEMBER 4TH, 2019

Prof. Adolf Mkenda, Permanent Secretary, MNRT,
Hon. Kemilembe Julius Lwota (MP) Chairperson, Parliamentary Committee for Lands, Natural Resources and Tourism,
Hon. Mrisho Gambo, Regional Commissioner, Arusha,
Dr. Maurus Msuha, Director of Wildlife, MNRT,
Dr. Simon Mduma, Director General TAWIRI,
Dr. James Wakibara, Conservation Commissioner, TAWA
Dr. Allan Kijazi, Conservation Commissioner, TANAPA
Dr. Freddy Manongi Conservation Commissioner, NCAA
Mr Bae, Yeon Jae, NIBR President,
Mr David Thompson, Deputy Mission Director, USAID,
Management of TAWIRI,
Conference Participants,

Excellencies, Distinguished Delegates, Ladies and Gentlemen,

Good Morning all!

First and foremost, I would like to thank the Almighty God for making this gathering possible and glad that you were all able to make it to this important gathering today. Also, allow me to extend my sincere gratitude to the Management of the Tanzania Wildlife Research Institute (TAWIRI) for inviting me to officiate the opening of the 12thTAWIRI Scientific Conference here in Arusha for the first time. **I feel greatly honoured**.

Conference Participants, Ladies and Gentlemen,
As a host Ministry, 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 traveled from abroad (UK, USA, Scandinavia, Asia and East Africa just to mention a few) to attend this meeting. Your presence is highly appreciated and signifies your support to TAWIRI and commitment to wildlife conservation in general. You are most welcome, and it is my hope that you will find the environment conducive enough for your serious deliberations in the next three days. “KARIBUNI SANA”.

Conference Participants, Ladies and Gentlemen,
TAWIRI is mandated to conduct, coordinate as well as dissemination of wildlife research findings to stakeholders in the country in order to provide guidance for conservation actions. These biennial conferences have not only been useful in enabling the Institute to fulfill this responsibility, but also provide information to foster long-term conservation in Tanzania and across the region. I’m

informed that one of the objectives of these conferences is to continually provide up-to date research results to help make informed decisions and promote the development of the wildlife industry in the country. I've been informed further that Proceedings of the previous 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. I would also like to direct TAWIRI to ensure timely production and distribution of same to relevant stakeholders. Beginning from this conference henceforth, Conference Proceedings should be made available three months after the conference.

Conference Participants, Ladies and Gentlemen,
The Ministry of Natural Resources and Tourism recognizes the importance of TAWIRI scientific conferences as a platform for disseminating research findings in the country. In this regard, my Ministry will continue to support these conferences to the best of her ability. My Ministry further recognizes a wide range of stakeholders in the wildlife sector who are end-users of the findings generated by researchers; your continued 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 continue participating in these conferences so as to keep pace with the ongoing challenges facing conservation of natural resources in the country and together to address them.

Conference Participants, Ladies and Gentlemen,
The theme of this conference is "A sustainable future for Tanzania's Biodiversity Conservation: The science behind priority, strategy and benefit". As a country, I must (and you may also possibly) admit that we have done fairly well and we are perhaps the best model in Africa and the world at large in wildlife conservation. The country's wildlife protected area network is exceptional with about 40% of the total land area designated for biodiversity protection of which 50% is devoted to wildlife conservation in protected areas where no human settlement is allowed (National Parks and Game Reserves) and a remaining 50% where wildlife co-exist with humans. However, our natural rangelands have been decreasing in size over the last five decades due to the increasing population of human and livestock in rural Tanzania. In 1961, Tanzania had a population of 9 million people but now the figure is six-fold. On the other hand, cattle numbers have increased from around 12 Million in 1980s to the current estimate of 32 million. In recent years, my Ministry has been working hard to prevent or remove herds of livestock in protected areas, but this has been recurring from time to time and we need to collectively bring this to rest.

Conference Participants, Ladies and Gentlemen,
It is evident that human activities are progressively reducing the planet's life-supporting capacity at a time when rising human numbers and consumption are placing increasingly heavy demands on it. Trade off between human needs and sustainable conservation of our natural resources requires reliable information, generated through sound scientific research. This will enable decision makers to prioritize and strategies on future development of both. I, therefore, call upon you scientists to help us on this front. Often times you blame us politicians for making decisions such as establishing conservation areas that are smaller in size or misplaced, but what would you do as a decision-maker if information to guide conservation action is readily available? Please do your part and we will do ours. You scientists have the ability to generate useful knowledge to guide conservation actions and us politicians have the ability to sell this to the general public and to make things happen, let us work together!

Conference Participants, Ladies and Gentlemen,

To my opinion, conservation must be combined with appropriate measures in order to meet short term economic needs. The vicious circle by which poverty causes ecological degradation which in turn leads to more poverty can be broken largely by development. But if it is not to be self-defeating, it must be development that is sustainable and conservation helps to make it so. The development efforts of many developing countries are being slowed or compromised by poor conservation practice. For example, the expansion of formal and informal irrigation and associated encroachment of the Usangu Plains upstream of RUNAPA has denuded the watershed ecosystem services and reduced the once-perennial Great Ruaha River to a seasonal watercourse.

Conference Participants, Ladies and Gentlemen,

Trade-offs, can be considered as a sample of what might happen in other basins in the medium-term (for example in Pangani or Kilombero), require integrated planning and management across users at the watershed, landscape and ecosystem levels. Throughout the developing world the lifetimes of hydroelectric power stations and water-supply systems are being cut as reservoirs silt up because siltation is accelerated by deforestation, overgrazing and other unwise land uses. There is a close relationship between failure to achieve the objectives of conservation and failure to achieve the social and economic objectives of development or, having achieved them, to sustain that achievement. Hence our goal should be to integrate conservation and development to ensure that modifications to the planet do indeed secure the survival and wellbeing of all people.

Conference Participants, Ladies and Gentlemen,

Conservation needs to be applied cross-sectorally not an activity sector in its own right. In the case of sectors such as agriculture, fisheries, forestry and wildlife, conservation is that aspect of management which ensures that utilization is sustainable and safeguards the ecological processes and genetic diversity essential for the maintenance of the resources concerned. I, therefore,urge researchers to integrate research findings with all these sectors to make findings more robust and informative. Furthermore, I challenge TAWIRI to ensure they take aboard other sectors of relevance in all future conferences in an effort to attain common understanding and deliberations on the cross sectoral challenges.

Conference Participants, Ladies and Gentlemen,

I understand that research and innovations have been acknowledged as a critical factor for driving long-term sustainable economic growth and, alongside, employment creation, poverty alleviation and sustainable conservation of wildlife resources in different parts of the world. While I commend scientists for their contribution towards wildlife conservation through the 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 Human-Wildlife Conflict. I understand that most of the long-term research work has focused on biology and ecology of wildlife and would like to thank you for that. However, given the ongoing government efforts to curb illegal hunting, we anticipate greater wildlife movements at the interface, hence increased human-wildlife conflicts in the near future and therefore urge more research in this area.

Second, I call upon wildlife research scientists to consider investing on issues related to habitat loss, particularly in areas adjacent to protected areas and corridors. According to the recent report (NAFORMA) jointly funded by my Ministry, FAO and Ministry for Foreign affairs of Finland, Tanzania is losing around 400,000 hectares of forest per year, which equals an average annual deforestation rate of 1%. Between 1990 and 2005, our country has lost a total of 15% of its forest cover. This is a matter of grave concern to all of us and science must offer guidance on the better way forward here.

Conference Participants, Ladies and Gentlemen,
As we all know that research requires huge resources, let me take this opportunity to request development agencies and conservation partners to continue supporting existing research and new initiatives. I am grateful to note that cooperation already exists between TAWIRI with the following organizations: European Union, The World Bank, United Nation Development Programme (UNDP), USAID, Frankfurt Zoological Society (FZS), The World Wide Fund for Nature (WWF), Ngorongoro Conservation Area Authority (NCAA), Tanzania National Parks (TANAPA), Wildlife Division (WD), Grumeti Fund, National Research Foundation of Korea, Wildlife Conservation Society (WCS), Friedkin Conservation Fund, Centre for Biothreat Preparedness, Safari Club International Foundation, Vollmar Natural Lands Research Group, TANESCO, Bio-Top Tanzania Ltd and Vulcan Inc. just to mention a few.

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 "Tanzania Unforgettable and Zanzibar'', and specifically to Arusha – 'The City of Destiny', which is surrounded by a diversity of attractions within easy reach 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 the 12th TAWIRI Scientific Conference officially opened.

ASANTENI SANA!

CLOSING REMARKS BY THE DEPUTY PERMANENT SECRETARY; MINISTRY OF NATURAL RESOURCES AND TOURISM, DR. ALOYCE K. NZUKI; AT THE TWELVETH TAWIRI SCIENTIFIC CONFERENCE HELD AT ARUSHA INTERNATIONAL CONFERENCE CENTRE (AICC), ARUSHA, DECEMBER 4th - 6th, 2019

Dr. Maurus J. Msuha, Director of Wildlife
Dr. Simon R. Mduma, Director General TAWIRI,
Conservation Commissioners: TANAPA, TAWA and NCAA,
TAWIRI Management Team,
Conference Sponsors,
Distinguished Guests,
Conference Participants,
Ladies and Gentlemen:

I am honoured to join you here this afternoon, to officiate the closing of the twelfth TAWIRI Scientific Conference. I am delighted to see the attendance of the renowned and seasoned scientists and other senior researchers from within and outside of Tanzania. Your presence to this conference is highly appreciated and it is a clear testimony to your commitment and dedication to TAWIRI and wildlife conservation endeavors. I am aware that this conference has attracted more than 250 participants from different parts of the world. This attendance attests that this forum is important not only to wildlife scientists but also to the natural resource management authorities. I encourage you all to keep up spirit.

Ladies and Gentlemen,
The theme of this conference is "A sustainable future for Tanzania's Biodiversity Conservation: The science behind priority, strategy and benefit". I am confident that the wide spectrum of presentations totaling 120, which focused on this theme, has made important contributions to the conservation of wildlife and biodiversity in general. Equally, there have been a lot of constructive challenges raised by researchers to the management authorities and policy makers. Similarly, I ask the natural resource management authorities, to make effective use of the research findings presented at this conference for sustainable conservation of our flora and fauna.

Ladies and Gentlemen,
I have noted the wide spectrum of presentations under the ten sub-themes, namely:

1. Natural resource governance and infrastructure development;
2. Human-wildlife interactions and land-uses;
3. Wildlife diseases and ecosystem health;
4. Wildlife ecology and ecological interactions;
5. Climate change and wildlife conservation;
6. Biodiversity inventory of flora and fauna;
7. Hydrology and wetland resources conservation;
8. Wildlife habitat, rangelands and invasive species;
9. Vegetation ecology and ethno-botany; and
10. Beekeeping, bee ecology and api-tourism.

These papers which focused on conference theme are important contributions to the conservation of wildlife and biodiversity, and therefore it would be useful if all presenters could submit final papers for early production of the proceedings, so we can have them all readily available. I believe that the published proceedings of the 12th TAWIRI Scientific Conference will provide scientific information that will support conservation of both flora and fauna to all stakeholders in biodiversity conservation. But allow me to underscore one offshoot from the presentations, namely api-tourism. This type of tourism, aims at raising awareness as to the importance of bees to mankind, enriching knowledge about the use and effects of bee products and api-therapy, and enhancing people's well-being. It is a new phenomenon in Tanzania, and I believe it is the case with many other developing countries. We are used to developing agri-tourism, which is mostly rural based. It is now time, we paid more attention to api-tourism, as a strategy for developing rural tourism. I therefore urge TAWIRI to work with the modern beekeepers and the tourism fraternity in seeing to it that api-tourism becomes yet another significant product, along with cultural tourism and agri-tourism. Similar efforts may be emulated elsewhere.

Ladies and Gentlemen,
I understand that organizing a conference like this one is very costly. So, before I vacate the podium, allow me to, on behalf of TAWIRI, express my appreciation to the sponsors of this conference. These include, the Ministry of Natural Resource and Tourism; Tanzania National Parks (TANAPA); Ngorongoro Conservation Area Authority (NCAA); Tanzania Wildlife Management Authority (TAWA); Grumeti Fund; Oikos; The Nature Conservancy (TNC); Frankfurt Zoological Society (FZS); the UAG Group; Jane Goodall Institute (JGI); Gadgetronix; NOMAD (T) LTD Trust; Friedkin Conservation Fund; Chem chem Association; USAID-Protect; Wild Dog Project; Asilia Hotels LTD; Miracle Experience; and last but not least, the Arusha International Conference Centre (AICC). I hope I have not left anyone out. I want to take this opportunity to call on other organizations to emulate this spirit of supporting TAWIRI in all research activities and the coming scientific conferences.

Furthermore, allow me to thank the organizing committee for making this conference a success. We also thank the conference moderators for steering the deliberations of this conference. Equally important, our appreciation goes to you participants for setting aside the time to attend and actively participate in the conference here in Arusha, Tanzania. It is my fervent hope that the outputs of this conference have met the expectations of every one of us.

Ladies and Gentlemen,
To our guests who have made thousands of kilometers here, I hope that you have had an enjoyable stay in Arusha: 'the City of Destiny', Tanzania's Conference City and Headquarters of the East African Community. Please, find time after this conference and visit our tourist attractions around here, including Arusha National Park; Tarangire National Park; Manyara National Park; Ngorongoro Conservation Area; and perhaps to as far as the Serengeti National Park; to enjoy the magnificent nature that God has endowed us with as well as the rich culture and heritage resources.

Ladies and Gentlemen,
With these few remarks, I wish you a Merry Christmas and a Happy New Year, 2020; and safe travels back home; and now I humbly declare the twelfth TAWIRI Scientific Conference officially closed. See you again at the 13th TAWIRI Scientific Conference!

THANK YOU FOR YOUR ATTENTION.

RESOLUTIONS FOR THE 12TH TAWIRI SCIENTIFIC CONFERENCE, HELD ON 04TH - 06TH DEC. 2019, ARUSHA INTERNATIONAL CONFERENCE

Based on the expertise of the conference participants and the mandate of TAWIRI, this conference is

Noting the **vision of the government**[1] of Tanzania that nature, biodiversity and wildlife are important aspects for the sustainable economic growth model of the country, motivating it to keep 40% of its land surface well-protected for nature following the National Biodiversity Strategy and Action Plan 2015-2020.

Noting that the current **quality of scientific research in Tanzania is strong**[2], and that most of the outcomes of these researches are helpful in securing a sustainable future for Tanzania's biodiversity conservation and associated livelihoods of people.

Recognizing the **responsibility of TAWIRI**[3] and its biannual conference to formulate recommendations on priorities, strategies, and expected benefits of conservation of biodiversity.

Recognizing the **recent conclusions of the IPBES**[4] International Program on Biodiversity and Ecosystem functioning that nature and nature's contributions to people are vital for human existence and a good quality of life, especially in the light of the expected doubling of the human population of Tanzania in the next 30 years.

Noting that the **population of Tanzania will double in the next 30 years**[5] , putting a large pressure on how natural resources can continue to contribute to the livelihoods of people and their cultural heritage.

Noting that human driven climate change, mostly driven by industrialized countries, will lead to **growing climatic extremes**[6] in East Africa expressed as increased variability in rainfall, where for example the huge floods of October to December 2019 likely will be followed by significant droughts, with large potential effects on food production.

Noting that nature reserves and particularly upland forest reserves provide critical buffers to droughts, through functioning as 'water towers', supplying a continuous releases of fresh water to rivers that support people, agriculture and livestock in neighboring dry lands.

Recognizing that the current setting aside of **40% of the country land as protected area and its effective management for wildlife**[7] are important preconditions to Tanzania's ambition of nature-based economic growth, as supported by the recent IPBES synthesis that shows that nature is not only "nice to have" but also a "need to have", especially in the light of forth coming population growth and climate change.

Based on the scientific evidence presented during the conference , this conference is [7]

Concluding that degradation within protected areas is growing as a consequence of unsustainable levels of illegal grazing, logging, bush meat consumption, predator poisoning, and invasive species, threatening the integrity of these ecosystems and their abilities to continue to provide benefits to people over the next decades.

Concluding that negative impacts of people within strictly protected areas (national parks, game reserves, forest reserves) are magnified by **climate change and invasive species**.

Recommending that there is a need for stronger reinforcement of, and adherence to regulations and laws to **stop deforestation** in the remaining forests, as these increasingly play a key role as 'water towers' in the adaptive capacity of Tanzania to cope with global climate change, especially towards the expected increased severity of droughts.

Recommending that there is an urgent need to evaluate and increase research efforts in the spatial **zoning of wildlife tourism** infrastructure in highly visited areas such as Serengeti NP, Ngorongoro CA and Kilimanjaro NP, as preliminary data analyses suggest an unexpected high negative impact of tourism on wildlife, potentially impairing the long-term economic benefits of tourism.

Recommending that for the long-term growth of the tourism industry, a **diversification of tourism** is needed beyond upper market international wildlife tourism in parks, towards e.g. agricultural, biking, backpacking, coastal and other forms of tourism development, especially outside protected areas.

Concluding that the **coexistence of humans and wildlife** in multiple use areas (as in Conservation Area, controlled areas and Wildlife Management Areas) is **rapidly breaking dow**n, mostly due to increases in livestock populations beyond sustainable levels, expanding agriculture and insufficient implementation of laws and regulations.

Concluding that multiple use areas are seeing **increased human-wildlife conflicts across soft conservation borders**, which will be strongly accelerate in the face of the expected doubling of the human population over the next 30 years, in combination with increased climatic extremes, requiring novel solutions for how to retain zones where people and wildlife still coexist in Tanzania, and the key ecosystem services (including tourism benefits) associated with this land use

Concludes that without change in policies, the current trajectory of Tanzania is towards **hard borders** between (fenced and small) protected areas and human-dominated rural and urban landscapes, a protected area conservation strategy that is however likely to cause a large-scale degradation of human's benefits from nature and thus is unsustainable

Recommending that if the government instead aims to maintain soft borders between people and wildlife in the face of the doubling of its human population, substantial **interventions** are needed that re-balance incentives (benefits and costs are fairly and transparently distributed), interventions (clear rules are set and enforced) **and trust** (communities are heard and trusted in their natural resource management), especially in the WMAs.

Recommending that there is an urgent need for the implementation of **effective corridor**s to protect remaining landscape-level wildlife movements, as despite the extensive ongoing conservation effort in Tanzania many of its protected areas critically depend upon connecting other habitats (protected or unprotected) at the landscape scale, such as wet-season dispersal and calving areas for wildlife

Recommending that there is an urgent need for a strategic **re-evaluation of spatial priorities** that consider simultaneously ecological connectivity, tourism potential, water storage capacity, biodiversity preservation, human migrations to yet little developed areas, associated agricultural expansion and grazing potential, where the separation of these issues in different ministries makes the development of integrated solutions challenging.

Recommending the development of an integrated **national cross-sectoral strategy for sustainable land use**, including considerations on human livelihoods, health, role of women, spatial priorities (zoning, corridors, special-value areas), agricultural, mining and urban development, and the most recent natural and social science insights, and make sure that this strategy is **rapidly implemented in high priority areas**, i.e.,areas now undergoing the most rapid losses in human's benefits from nature.

[1] as formulated by Honorable Minister of Natural Resources and Tourism of Tanzania at the opening of the TAWIRI conference

[2] http://tawiri.or.tz/wp-content/uploads/2017/08/national-biodiversity-strategy-and-action-plan-2015-2020.pdf

[3] http://tawiri.or.tz/

[4] https://ipbes.net/news/global-assessment-summary-policymakers-final-version-now-available

[5] https://population.un.org/wpp/Graphs/Probabilistic/POP/TOT/834

[6] See p. 1210 in https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap22_FINAL.pdf

[7] See the presentations held at the meeting and the published conference abstracts: "A sustainable future for Tanzania's biodiversity conservation: The science behind priority, strategy and benefit. TAWIRI, December 2019"

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ACKNOWLEDGEMENT

Tanzania, through the Ministry of Natural Resources and Tourism for making this 12th TAWIRI Scientific Conference a successful event. TAWIRI acknowledges all delegates; majority being researchers, academicians and conservationists who attended the conference. Particular mention is made on those who prepared presentations, round table discussions, symposium and workshop that have enriched this conference with valuable conservation information. We also express our sincere thanks to all conservation authorities, institutions, organizations and private companies for both material and financial support that made the 12thTAWIRI Scientific Conference successful. The Institute acknowledges their valuable contributions and requests them to continue supporting TAWIRI to achieve the same in future. TAWIRI wish to recognize both material and financial support received from the conference sponsors. These organizations are not only our recurrent supporters to this particular event, but also support a wide array of conservation and research activities in the country. We sincerely thank the organizations (whose logos are shown below) and urge them to please keep up the spirit! Special thanks goes to the Conference Organizing Committee which worked tirelessly to make the event possible.

ETHNOVETERINARY PLANT REMEDIES USED BY LIVESTOCK KEEPERS IN NORTHERN TANZANIA

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ABSTRACT

Despite the increasing use of modern veterinary services to cater for livestock health care needs, traditional phytotherapy remains a prominent alternative medical practice for livestock. This is especially so in areas of rural Tanzania where infectious diseases are rampant and modern veterinary services are insufficiently provided. However, the existing indigenous knowledge about ethnoveterinary practice remains inadequately documented in these areas. In this study, we aim to better understand and to document the indigenous knowledge associated with the use of plants for veterinary purposes by small-scale farmers in selected districts (Moshi, Hai, Siha, and Meru districts district in Northern Tanzania. Structured and semi-structured interviews were used to collect ethnobotanical data from livestock keepers. We determined and presented the fidelity level, frequency index, and informant consensus factor as quantitative measures of the use of ethnoveterinary plants reported. We found a total of 54 ethnoveterinary plant species belonging to 51 genera and 35 families used to treat 34 kinds of livestock diseases. Most ethnoveterinary formulations were extracted mainly from the leaf (59%) and bark (20%) which were prepared in the form of a paste and administered orally (77%). Further results show that 77.1% of the formulations were prepared by plant materials obtained from a single species while 22.9% were prepared from more than one plant species. In terms of the quantitative indices, we found Aloe vera (L.) Burm, and Aloe volkensii Engl. with the highest frequency indices (40.5 each) for treating Newcastle in poultry, and anti-diarrhoea in cattle, respectively. The highest fidelity levels were found in *Capsicum frutescens L.* (100) and *Kigelia Africana L.* (100) both responsible for treating Newcastle in Chicken, and Ficussycomorus (Lam.) Benth(100) for relieving birth complications in cattle. High fidelity and frequency indices suggest high veterinary importance of the reported plants in the study area. Also, the study indicates that informant consensus factor values ranged from 0.75 to 0.92. The Newcastle and respiratory ailment categories had the highest informant consensus factor value of 0.92 with 103 use-reports, referring to the use of 9 plant species. The high use of ethnoveterinary plant remedies for healing ailments in livestock highlights the need for government support of initiatives aimed at preserving this knowledge as an alternative livestock health care practice.

Keywords: Ethnoveterinary plants;informant consensus factor; fidelity level; frequency index; livestock ailments; phytotherapy

INTRODUCTION

Since time immemorial, medicinal plants have been used by tribal people to prevent and treat different livestock ailments (Abo-el-sooud, 2018; Jayakumar, *et al.*, 2018). Although there has been a shift from direct use of plant formulations to modern drugs for livestock healthcare, the latter remains a critical complementary ethnoveterinary practice in areas where infectious diseases are rampant and modern veterinary services are insufficiently provided (Amri & Kisangau, 2012; Shen, Qian, & Ren, 2010). Given their extensive range of knowledge in ethnomedicinal plants, tribal people remain the ultimate resource for retrieving this information for further discovery of modern drugs (Luseba & Tshisikhawe, 2013).

Several studies have assessed traditional knowledge associated with the use of plant medications to prevent and treat diseases in humans and animals (e.g. Gazzaneo, *et al*., 2005; Ijaz *et al*., 2016; Jamila and Mostafa, 2014). While the focus of ethnobotanical studies in Tanzania has been on exploring the indigenous knowledge associated with utilization of medicinal plants for human healthcare, there have been few studies which attempt to examine ethnoveterinary practices in preventing or controlling livestock ailments. Ethnoveterinary studies are reported in other African countries including but not limited to: Namibia (e.g. Chinsembu *et al*., 2014); Ethiopia (e.g. Eshetu *et al*.,2015; Giday, Asfaw, & Woldu, 2009); Zimbabwe (e.g. Maroyi, 2012); Nigeria (e.g. Odugbemi, *et al*., 2004); and Kenya (e.g. Muthee *et al*., 2011).

Like in these countries, a few qualitative studies have shown that most small-scale farmers in Tanzania rely on traditional remedies for treating livestock ailments (e.g. Kioko, Baker, Shannon, & Kiffner, 2015; Minja, 1994; and Amri & Kisangau, 2012). In rural areas where most small-scale farmers are found, veterinary services are limited due to a shortage of synthetic drugs, lack of skilled veterinarians, and insufficient financial capacity of farmers to pay for modern veterinary services. Because of this situation, the use of traditional medications is considered a prominent alternative medicine for treating various diseases in livestock (Nahashon, 2013). Despite the increasing loss of plants and its importance in veterinary services (Martínez & Luján, 2011; Pande, Tiwari, & Pande, 2007) in livestock keeping hotspots in Tanzania, the existing local knowledge which covers measures of uses of plant medications for livestock healthcare remains inadequately documented (Maregesi & Mwakalukwa, 2015; Moshi, Otieno, & Weisheit, 2012). In this study, we aim to document local knowledge associated with ethnoveterinary plants and quantify the extent of their use through indices of fidelity, frequency, and informant consensus factor in the selected districts in Northern Tanzania. Searching for ways to preserve this ethnoveterinary knowledge is a cornerstone to discovering the healing activity of medicinal plants (Khan *et al*., 2011). The findings from this study provide a scientific basis for future studies to evaluate the pharmacological efficacy of the reported ethnoveterinary plants (Hamisy *et al*., 2000). Also, the ethnoveterinary knowledge of plants documented in this study can help in developing a conservation management plan of medicinal plants to ensure their sustainability.

MATERIALS AND METHODS

Study area

This ethnobotanical study was conducted in Moshi, Hai, Siha, and Meru districts situated in Northern Tanzania (Figure 1). These districts are characterized by diverse climatic conditions that support varieties of plant communities ranging from savannato forests. These plant communities support myriads of plant species with curative properties. The four districts in which ethnobotanical sampling was conducted, border Kilimanjaro and Arusha National Parks, and forest reserves which are primary sources of wild medicinal plants for tribal people. The districts are dominated by Chagga, Maasai, Pare, and Meru communities who are either settled farmers in the highlands or pastoralists in the lowlands. While most farmers in these districts rely on modern drugs for prevention and control of various diseases in livestock, yet ethnoveterinary herbal medications are still used as complementary remedies

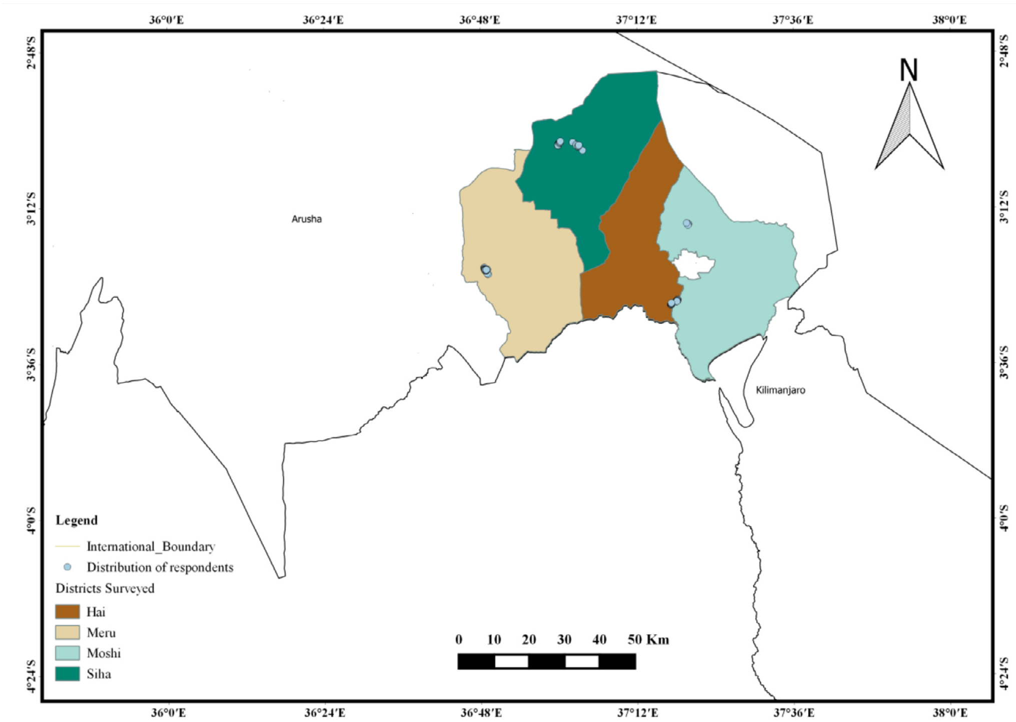

Fig.1. Map of the study area

Data collection

Ethnobotanical data were collected in Moshi, Hai, Siha and Meru districts using structured and semi-structured interviews with livestock keepers, traditional healers and veterinary officers as described by Martin (1995). Snowball sampling technique was used to select respondents for providing knowledge and experience on how to use ethnoveterinary plants for veterinary purposes. In this study, we interviewed a total of 161 livestock keepers were interviewed. Besides that, we collected specimens and identify all reported ethnoveterinary plants species through direct observation in villages and nearby natural areas. Data collected included local names of plants, parts of plants used, livestock species, and types of ailment treated, methods of dosage preparation, and mode of administering medications to livestock. Taxonomic identification of herb and woody plant species with veterinary values was done according to Van Wyk & Malan, (1997) and Van Wyk & Van Wyk, (2013) respectively.

Data analysis

Descriptive statistics like percentage and frequencies were used to summarize demographic characteristics of respondents and ethnoveterinary plants data using Microsoft excel. Summary tables were constructed to report ethnoveterinary plant species with fidelity level, frequency index, informant consensus factors, and other parameters based on Amorim *et al*., (2012) approach. To test how the indigenous knowledge on ethnoveterinary plants vary between respondent's tribes, gender, location, and system of livestock keeping practised by respondents we used $\chi 2$ test in R software version 3.4.4 (R Core Development Team, 2018). Additionally, three quantitative indices, namely fidelity level, frequency index, and the informant consensus factor, were determined according to Amorim *et al*., (2012).

Fidelity level

Fidelity level is estimated as a proportion of the healing potential of each plant species reported to treat a particular livestock ailment (Tariq *et al.*, 2014; Tumoro & Maryo, 2016). We calculated the fidelity level for the most useful ethnoveterinary plants either cited more than ten times, or they are used to treat more than one identified livestock ailment. Calculation of fidelity level was done according to Uddin & Hassan (2014), as shown in equation (i). A high value of fidelity level shows high use frequency by the informants in treating a particular livestock ailment and vice-versa. We presented the fidelity level of only 15 common ethnoveterinary plant species.

FL=FL= Np / Nu × 100%-----------------------------(i)

Where;

FL = Fidelity Level

Np = Number of informants claimed the use of a plant species in treating a particular ailment

Nu = Number of informants that use the plants to treat a given livestock ailment

Frequency index

To compare the relative importance of each ethnoveterinary plant reported, we calculated the frequency index according to Chinsembu et al., (2014) as shown in equation (ii). In this case, a frequency index is high when many informants cited a particular plant and low when there are few reports about that particular ethnoveterinary plant species (Chinsembu et al., 2014).

FI = FC/N X 100------------------------------------ (ii)

Where;

FI = Frequency index

FC = Number of informants who cited the use of a particular ethnoveterinary plant

N = Total number of informants interviewed in the study area

Informant Consensus factor

We also calculated the informant consensus factor to determine the level of the agreement of information provided by different informants regarding the use of plants in treating a specific livestock ailment category. The informant consensus factor was calculated according to Tumoro & Maryo (2016), as shown in equation (iii). Before calculating the ICF, the reported ailments were grouped into eight categories and plants used in the treatment of each ailment category were identified. Usually, ICF ranges from 0–1, whereby high ICF (close to 1.0) shows that there is a distinct group of species used by a large proportion of informants to treat a particular ailment category. A low ICF value (close to zero) indicates that informants disagree over which plant species to use in treating a particular ailment category (Gazzaneo *et al*., 2005). To calculate the ICF, the cited species were grouped according to ailments categories they are used to treat i.e. Gastrointestinal diseases; dermatological and related problems; brain and nervous system; gynecological, andrological and urogenital; parasitic diseases; jaundice; Newcastle and respiratory diseases; and miscellaneous ailments. Newcastle disease respiratory diseases were grouped together because Newcastle in poultry starts as an acute respiratory disease. Miscellaneous category included health complications to livestock that were not well defined by the interviewees such as general body weakness, fever and problems believed to have been resulted from evil spirits (Amorim et al., 2012).

ICF = Nur – Nt / (Nur – 1)--------------------(iii)

Where;

ICF = Informant consensus factor

Nur= Number of use reports from informants for a particular ailment category

Nt= Number of plant species that are used for an ailment of a particular category for all informants.

RESULTS

Demographic characteristics

Respondents comprised of 52.2% (n = 84) males and 47.8% (n = 77) females. It was found that 80.1% (n = 129) of respondents had formal education and 19.9% (n = 32) had no formal education. Also,47.8% (n =77) of livestock keepers do practice zero grazing, 12.4% nomadic pastoralism (n = 20), and 39.8% (n = 64) semi-sedentary pastoralism. About 31.7% (n = 51) of respondents were Chagga, 22.4% (n = 36) Meru, 12.4% (n = 20) Maasai, 11.8% (n = 19) Pare, and 21.7% (n = 35) were combination of tribes which were represented by a few respondents.

Ethnoveterinary knowledge

Results showed that knowledge associated with ethno veterinary plants was significantly higher to males than females ($\chi2$ = 9.1049, $p<0.05$), suggesting that men are more knowledgeable women. Further results show that knowledge of respondents on ethnoveterinary plants for preventing or treating livestock ailments was found to be associated with the ethnic group of the respondent ($\chi2$ =15.621, $p<0.05$), and system of livestock keeping practiced by respondents ($\chi2$ = 7.6999, $p<0.05$).

Reported plants with veterinary uses

A total of 54 plant species were reported to be used by respondents for preparing phytotherapy for preventing or treating various ailments in livestock the study area. Majority of plant species with ethnoveterinary uses were trees (46%) followed by shrubs (24%) and herbs (13%) (Fig. 2). We also found ethnoveterinary plants belonging to 51 genera and 35 families. *Fabaceae* was the most diverse family being represented 13% (7) species, closely followed by *Euphorbiaceae* and *Asteraceae* families 7.4% (4) species each. The remaining 32 families were represented by one to a maximum of two species (Fig. 3).

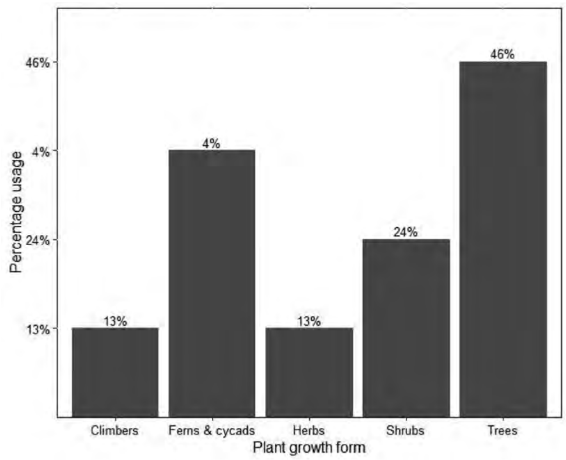

Fig.2. Distribution of plants into different life forms. Bars show the percentage of identified ethnoveterinary plants in each growth habit category

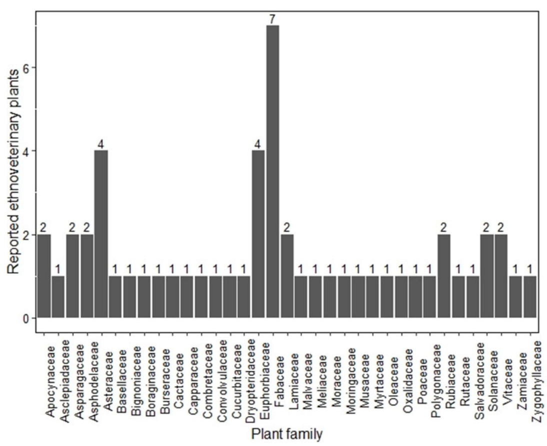

Fig.3. Distribution of plants in different families. Bars indicate family and number of ethnoveterinary plants reported

Plant parts used, means for preparation and dosage administration.

Results indicate that plant remedies for livestock ailments are prepared from the leaves (59%), barks (20%), fruits (8%), roots (7%), sap (3%) and whole plant (3%) (Fig. 4). Conventional methods used to prepare traditional medication for treating or preventing livestock ailments included infusions (29%), defections (17%), macerated leaves (15%), grinding of barks (8%) and burning some plant parts to create smoke (5%) (Fig. 5). The remaining proportion included medications taken directly by livestock as part of the fodder (26%) (Fig. 5). Of all preparations, only 22.1% were reported as a mixture of plant materials from one or more species with additives such as milk or salts, while the remaining 77.9% contained materials from a single plant species alone. We also found that 77% of the preparations were administered orally while others were reported to be applied externally, steam inhalation and aroma sniffing, and smoke of burnt plant materials (Table 1 and Fig. 6).

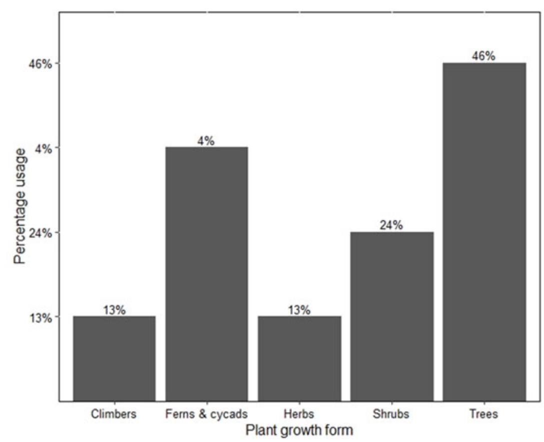

Fig. 4. Part of plants used for preparing a traditional dosage for treating or preventing livestock ailments

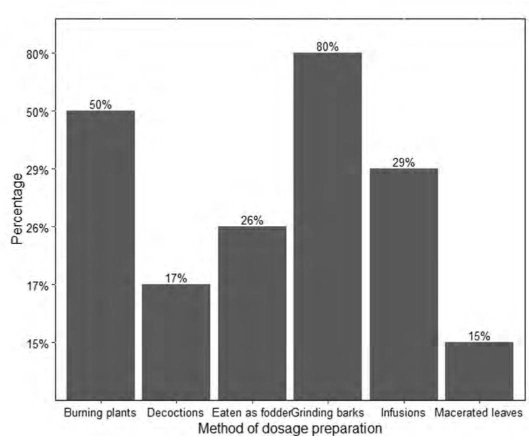

Fig. 5. Methods of preparing an ethnoveterinary dosage and frequency of citations by livestock keepers

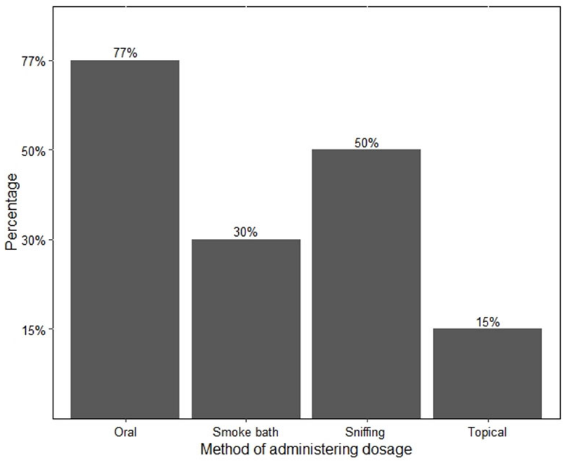

Fig. 6. Methods of dosage administration applied. Bars show the percentage of respondent's citations for a particular method

Fidelity level (FI)and practices of the ethnoveterinary plants

We found that Aloe vera (L.) Burmand Aloe *volkensii Engl.* have the highest FI (40.45) each. *A. vera* and *A. volkens*i were frequently reported to treat Newcastle in poultry, and anti-diarrhoea in cattle, respectively. Also, we report a narrative of all ethnoveterinary plants reported during this study, families, local names, part used, animal treated, ailment treated, dosage preparation and administration.

Informant Consensus Factor (ICF) of the reported ethnoveterinary plants

In this study we found the ICF values ranging from 0.75 to 0.92. The Newcastle and respiratory ailments had the highest ICF value of 0.92 with 103 use-reports referring to the use of 9 plant species (Table 2). Other ailments categories include Jaundice (0.88), parasitic diseases (0.87), brain and nervous system (0.80), gynaecological, andrological and urogenital (0.79), dermatological and related problems (0.79), gastrointestinal problems (0.78) and miscellaneous (0.75) for ailments were also reported by respondents (Table 1).

Table 1: Informant consensus factor for each livestock ailment categories

Ailment categories treated	Nt	Nur	ICF
Newcastle and respiratory diseases	9	103	0.92
Jaundice	6	42	0.88
Parasitic diseases	10	69	0.87
Brain and nervous system	2	6	0.80
Gynaecological, andrological and urogenital	9	39	0.79
Dermatological and related problems	7	30	0.79
Gastrointestinal	18	79	0.78
Miscellaneous	11	41	0.75

Fidelity Level (FL) of the reported ethnoveterinary plants

The highest FL values for the fifteen most frequently reported plants were *C. frutescens* (Lam.) Benth (100.0) and *K. africana L.* (100.0) both responsible for treating Newcastle in Chicken, and F. sycomorus L. (100.0) for relieving birth complications in cattle. Other ethnoverterinary plants and their FL values are also reported as shown in Table 2.

Table 2. Fidelity level (FL) of frequently reported ethnoveterinary plants and livestock ailment category reported to prevent or treat.

Scientific name	Ailment treated	Np	Nu	FL
*Capsicum frutescens*L.	Newcastle	13	13	100.0
Ficussycomorus L.	Birth complications	10	10	100.0
Kigeliaafricana(Lam.) Benth	Newcastle	10	10	100.0
Euphorbia candelabrum Kotschy	Babesiosis	8	10	80.0
Aloe vera(L.) Burm	Newcastle	62	78	79.5
*Aloe volkensii*Engl.	Newcastle	62	78	79.5
Croton microstachyus	Endoparasites	11	16	68.8
*Olea europaea*L.	East Coast fever	8	12	66.7
Cinchona officinalis L.	Trypanosomiasis	9	14	64.3
Tithoniadiversifolia(Hemsl.) A. Gray	Jaundice	11	20	55.0
*Ricinus communis*L.	Loss of appetite	6	11	54.5
*Rauvolfiacaffra*Sond.	Endoparasites, jaundice	12	22	54.5
*Cordia africana*Lam.	Lumpy skin disease	10	19	52.6
*Azadirachtaindica*A. Juss.	Newcastle	9	20	45.0
Tetradeniariparia(Hochst.) Codd	Endoparasites	9	22	40.9

DISCUSSION

Ethnoveterinary knowledge

The knowledge on ethnoveterinary plants was found to vary based on gender, tribe, and type of livestock keeping system practices by respondents. This could be explained by the fact that animal keeping in Tanzania is culturally done by men rather than women and therefore, the transfer of ethnoveterinary knowledge is more obvious in men than women (Giday *et al*., 2009). Previous studies show that men were more knowledgeable on ethnoveterinary practices in many areas (Tariq *et al.*, 2014; Tumoro & Maryo, 2016). Differences in knowledge across tribes is mainly attributed to their differing ways of sharing and maintaining knowledge, innovation and practices relating to the uses and management of plant resources (Davis, 2008). This results in some tribes maintaining more knowledge than others. Systems of livestock keeping also affect the use of medicinal plants because differing systems expose livestock to infections to differing degrees. For example, cattle mobility in search of pasture and water predisposes animals to infections (Alhaji *et al*., 2018) more than zero grazing would. Factors such as high rate of infections and the failure to access healthcare services lead farmers using cattle mobility systems to opt for traditional plant remedies for preventing or controlling ailments in livestock. Contrary to that, livestock keepers practicing zero-grazing do not rely much on plant remedies due to good quality and nutritious feed, clean environment, reduced animal morbidity and interactions which eventually reduce exposure to zoonotic pathogens (Sudda, 2017). This, however, does not mean that livestock in zero grazing systems are void of ailments, they are also exposed to some infections (Nguhiu-Mwangi, et al., 2012;Tomley & Shirley, 2009).

Plants used for treating animal's ailments

Reported ethnoveterinary plants

We found that the most used ethnoveterinary plants belong to Fabaceae, followed by *Euphorbiaceae* and *Asteraceae* families. Most plants in Fabaceae, Euphorbiaceae and Asteraceae families have been widely reported to possess medicinal properties for curing various ailments in human and livestock because of the presence of a wide variety of secondary metabolites (Amri & Kisangau, 2012; Giday et al., 2009; Pande *et al*.,2007). Findings from this study are consistent with those obtained by Ziblim, Timothy, & Deo-Anyi, (2013) in the Northern regions of Ghana. On the other hand, members of the family Euphorbiaceae were also reported to possess veterinary values. Differential medicinal properties of the Euphorbiaceae are thought to be associated with its wide range of habitats which predispose plants in this family to high mutation loads hence the creation of defensive secondary metabolites which can have important healing properties (Moshi *et al*., 2012). In this study we also reported that, trees are the most commonly used life form. The high use value of trees could be attributed to the high richness and dominance of trees and agroforestry system practiced by inhabitants in the study area. This result matches the findings obtained by Muthee *et al*., (2011), who found trees to contribute to the largest portion of the medicinal plants identified in Loitoktok in Kenya.

Parts of plant used, and method preparation and administration of phytotherapy

Leaves were the most reported plant part used for preparation of medications for treating livestock ailments. High use value of leaves could be because harvesting of leaves is less destructive in comparison to harvesting roots and barks. This could be a strategy used by tribal people to conserve medicinal plants to ensure continuous supply. These findings are similar with those obtained by Amorim *et al.*, (2012) in Colares island in Brazil, Tariq *et al*., (2014) in Sulaiman Range, Jayakumar *et al*., (2018) of Konar community of Tamil Nadu and Kioko *et al*., 2015; and Minja, 1994) in Tanzania. Nevertheless, the use of leaves and other plant parts reported can pose severe threats to some rare and slowly reproducing plants if not identified and harvested sustainability. It is still premature to conclude that ethnoveterinary practices are conservation friendly. Further studies must be done to assess the quantity of plant parts harvested, dosage of medicine and status of these plants in the study area.

Further results show that most preparations were based on infusion (water-based preparation). This approach was commonly reported by respondents of this study as a means of preparing traditional dosage probably because of its effectiveness in making plant particles easily digestible and absorbed by the animals. These findings corresponds to those obtained by Luseba & Tshisikhawe, (2013) on ethnoveterinary plants in South Africa. Also, we found that most recipes were formulated by plant materials purely obtained from a single plant species (monotherapy) as compared to polyherbal preparations (mixtures of more than one medicinal plant species). Results reported by Mussarat *et al*., (2014) in Indus River depicted a similar pattern. The possible explanation for this practice could be due to the variation in indigenous knowledge across different ethnic groups involved in the study. Additives such as salts may also be added to ethnomedicine as a way to add tastes in the phytotherapies. Polyherbal preparation is common and has also been reported to be used in preparation of phytotherapies in other studies such as Eshetu *et al.* (2015). Oral route was found to be the most reported means of administering ethnomedicinal dosage. These findings are consistent with those of Eshetu *et al*. (2015) on preparation and application methods of ethnoveterinary medicine by traditional healers, which was conducted in Southern Ethiopia andin Buuri district, Meru County in Kenya (Gakuubi & Wanzala, 2012).

Quantitative indices for the reported ethnoveterinary plants. The highest fidelity values for *A. vera* and *A. volkensiiare* attributed by the pharmacological importance of the species of the family *Asphodelaceae* for curing different ailments in both humans and livestock (Grace *et al*., 2009; Mbambo, Odhav, & Mohanlall, 2012). For instance these plants have been widely reported to treat Newcastle in poultry (Grace *et al*., 2009; Mbambo, Odhav, & Mohanlall, 2012). High fidelity level for these species may have emerged from the fact that most people practicing poultry rearing are found where small scale poultry rearing practices acts as source of food and nutrition, as well as income and a way to improve their livelihoods (Guèye, 2000). *Aloe spp* are also believed to be used in treatment of multiple ailments such as laxatives, anti-inflammatories, immune-stimulant or antiseptics to both humans and livestock (Avasthi *et al*.,, 2011) as well as deworming agents for livestock (Lans,2007). For instance, Aloe vera is used for supportive therapy and prophylaxis in commercial poultry production, treating international injuries, and as purgative for ruminants in Trinidad and Tobago (Lans and Brown, 1998).

High ICF for Newcastle and respiratory category resulted from the use of *A. vera* and *A. volkensii.* Newcastle was reported to be a common poultry disease in the area, and so the knowledge of these plants' use is shared among people in curing the disease. This also means that there is a selection criterion in the medicine of these ailments and its usage information is well defined (Amorim *et al*., 2012). The miscellaneous category had low ICF because plants used to treat this ailment category are randomly chosen and thus informants do not exchange information about their use. This is also because this category had diseases which are not well defined and thus livestock keepers lack a specific criterion for their selection.

High FLs were obtained for *C. frutescens*, *K. africana* and *F. sycomorus*. Pharmacological studies and reviews have been done for C. frutescens (Al-snafi, 2019) where important bioactive compounds were isolated and studied for chickens infected with Newcastle disease K. africana (Adeparusi, 2010) in which its effect on sperm quality of African Catfish was determined and it was found to possess promising pro-fertility which can be exploited in fish seeds production and *F. sycomorus* (Oluwasesan, Agbendeh, & Adikwu, 2013), whereby its stem bark revealed to possess alkaloids, flavonoids, glycosides, reducing sugars, resins, saponnins and tannins. Other studies need to be done to provide evidence for the efficacy of these useful plants in dealing with animal ailments. The medical efficacy of these plants with relatively high FL which include but not limited to *E. candelabrum*, *A. vera*, *A. volkensii*, C. *microstachyus, O. europaeaand C. officinalis L* need to be studied. Some studies have also been done on plants which have low FL in this study which include *A. indica* (Maan, Yadav, & Yadav, 2017; Ranjit, Yogesh, & Aparna, 2015), and results have shown wound healing ability in both livestock and humans. Antimicrobial activity of *T. riparia* was assessed in a study by Njau, Alcorn, Buza, Chirino-trejo, & Ndakidemi (2014). Similarly, R. caffra was also found to have antimicrobial and antioxidant activities in a study by Njau, Alcorn, Ndakidemi, Chirino-trejo, & Buza, (2014) while C. africana was found to have anti-nociceptive activities (Tijjani et al.,2016).

CONCLUSION

In summary we found 54 plant species used in treatment of 34 livestock ailments by farmers in the study area. The Aloe vera, A*loe volkensii, Capsicum frutescens, Kigeliaafricana,* and *Ficussycomorus* were among the most commonly used species with the pharmacological importance of preventing or controlling various ailments in livestock in the study area. This study emphasizes a need to evaluate the pharmacological efficacy of the reported ethnoveterinary plants especially those with a high use value and number of citations for particular illness categories. This might provide potential leads in fulfilling the unmet needs in animal husbandry in rural Tanzania. Overall, high use of ethnoveterinary remedies in healing ailments in livestock highlights the need of government support for initiatives aimed at preserving this knowledge as an alternative livestock healthcare practices especially for farmers residing in areas where shortage of synthetic drugs, and lack of skilled veterinarians, and low financial capacity of farmers to pay for modern veterinary services exist.

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STATUS AND VULNERABILITY OF WILDLIFE TO ROAD ACCIDENTS IN THE SERENGETI ECOSYSTEM, TANZANIA

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ABSTRACT

Roads have detrimental impacts on wildlife populations around the world. However crucial this information is for wildlife conservation, little is known on the Serengeti ecosystem. This study employed a cross sectional observation method to document the status and vulnerability of wildlife to road accidents along major gravel road networks in the Serengeti ecosystem. Our results revealed 51 wildlife road kill belonging to 26 species. More wildlife were found killed during the morning (n = 36, 70.6 %) than the afternoon (n = 15, 29.4 %) hours. More small (n = 40, 78.4%) than medium to large bodied (n = 11, 21.6%) animals were recorded killed because of their high population densities which increase their frequency encounters and attempts to cross the roads which increased their likelihood of being hit by vehicles in the area. In addition, a relatively higher proportion of birds were killed (n = 31, 60.8%) than mammals (n = 20, 39.2%) species. Overall, the African hare (Lepus capensis) was the main victim (n = 9, 17.7%) followed by helmeted guinea fowl (Numida meleagris) (n = 6, 11.8%) among avifauna for the road kill in the area. Therefore, this study recommends for strengthening of fines, installing speed bumps, establishment of vehicle speed limit check points, installation of speed limit devices like solar powered cameras, and providing education on safety driving as well as enforcing laws and regulations by responsible management authority. Also new and existing scientific information on road accidents should be made available to decision makers and scientists for informed decision making during road design in protected areas.

Keywords: Amphibians, conservation, endemic, phylogeny, Uzungwa Scarp

INTRODUCTION

Roads have multiple effects on the ecology of terrestrial communities and are increasingly dominating features in continental landscapes. According to Avalos & Bermúdez (2016), roads in conservation areas would increase in number, size, and traffic over the next decade, and thus, understanding their effects on wildlife is crucial for improving current management practices and reducing the negative impacts of roads on biodiversity loss. Previous findings documented that roads traversing through protected areas have been designed to facilitate transportation of goods and services but their uses have been reported to adversely impact wildlife (i.e. road kills) in different protected areas worldwide (Bissonette and Kassar, 2008; da Cunha et al., 2010; Santos et al., 2011; Selvan et al., 2012; Williams et al., 2019). According to Teixeira et al. (2017), wildlife road kill can be defined as the animal mortality due to wildlife–vehicle collision. Also, it occurs because wildlife and people driving vehicles are on the road simultaneously, and cannot predict the behavior of one another (Magnus *et al*., 2004). Furthermore, a study by Kociolek & Clevenger (2009) reported that road construction and their density, can lead to significant loss of biodiversity at local, regional and landscape scales, the full effect of which may not be detected for decades. In addition, the study by Bager& Rosa (2010) reported that the effects of roads on biodiversity are related to the mortality of animals during the construction of a highway, mortality from collision with vehicles, modification in animal behavior, increasing the human use and occupation of the surrounding areas, habitat fragmentation, and introduction of exotic species. However, more information is available for protected areas in developed regions (Orlowski, 2005; Glista & DeVault, 2008; Freitas *et al*., 2013; Morelle *et al*., 2013). Previous studies have reported that road conditions, traffic volume, poor visibility and speed accelerate road kill incidences (Forman & Alexander, 1998; Dodd *et al.*, 2004; Kioko *et al*., 2015b). Moreover, the diversity of species killed by vehicles in protected areas is higher in tropics, and thus the conservation issue may become more relevant (Farmer & Brooks, 2012; Freitas *et al*., 2013). This problem has tremendously increased concurrent with increase in infrastructure development in the protected areas (Dodd *et al*., 2004; Selvan *et al.*, 2012; Morelle *et al*., 2013); as a result, globally there has been an increased scientific interest in wildlife road kills (Lunde *et al*., 2016; Lyamuya et al., 2016; Nkwabi *et al*., 2018) and road ecology (Fyumagwa *et al*., 2017), moreover wildlife road kills have the potential to significantly affect biodiversity of the area. Though, there is some information on wildlife road kills in few protected areas in Tanzania (Drews, 1995; Kioko *et al*., 2015a; Kioko *et al*., 2015b), little information has been documented in the Serengeti ecosystem (Lyamuya *et al*., 2016; Nkwabi *et al*., 2018). In addition, wildlife road kills do not occur randomly but are spatially clustered because wildlife movements that tend to be associated with specific habitats, terrain and adjacent land use types (Clevenger *et al*., 2001; Joyce & Mahoney, 2001). The wildlife that are often hit by vehicles are those which are attracted to spilled grain, road verges 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 in protected areas. Therefore, this study had to objectives that aimed at firstly investigating the status of wildlife roadkill by determining how many animals (birds & mammals) are killed or injured and from which family and order do they belong and secondly identifying which animals species (birds & mammals) are more vulnerability to roadkill as well as their roadkill patterns on the existing gravel road networks in the Serengeti ecosystem. We hypothesized that: Firstly, animal with small body (like hares, rodents and birds) size would be more killed than medium to large larger body size, this is because they are probably more abundant (Barthelmess & Brooks, 20101) and frequently attempting to cross the road (Brockie et al., 2009) and therefore increasing their chances of been hit by vehicles. Secondly, more wildlife would be found killed during the morning than evening session because they are more active foraging along roads during that time and some might have been killed during the night.

Study Area

The study was conducted in the Serengeti ecosystem in northern Tanzania. It extends to south-western Kenya 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 than 600 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 *et al.*, 2015). Its high diversity in terms of animal species is a function of diverse habitats ranging from riverine forests, swamps, kopjes, open grasslands and woodlands. The south-eastern part of the area is open grassland, the northern part largely wooded, and the western region is a mix of open and wooded areas. The open grassland zone receives inadequate rainfall to sustain fire, typically below 600 mm per year (Homewood *et al.*, 2004). 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 Vachellia, Balanites and Commiphora species with other broad leaved species such as Terminalia, Euclea and Croton as sub-dominates (Bukombe *et al.*, 2018) which dominate the intermediate grasslands and woodlands. The topography is highly variable, with catena effects having important influences on woody species.

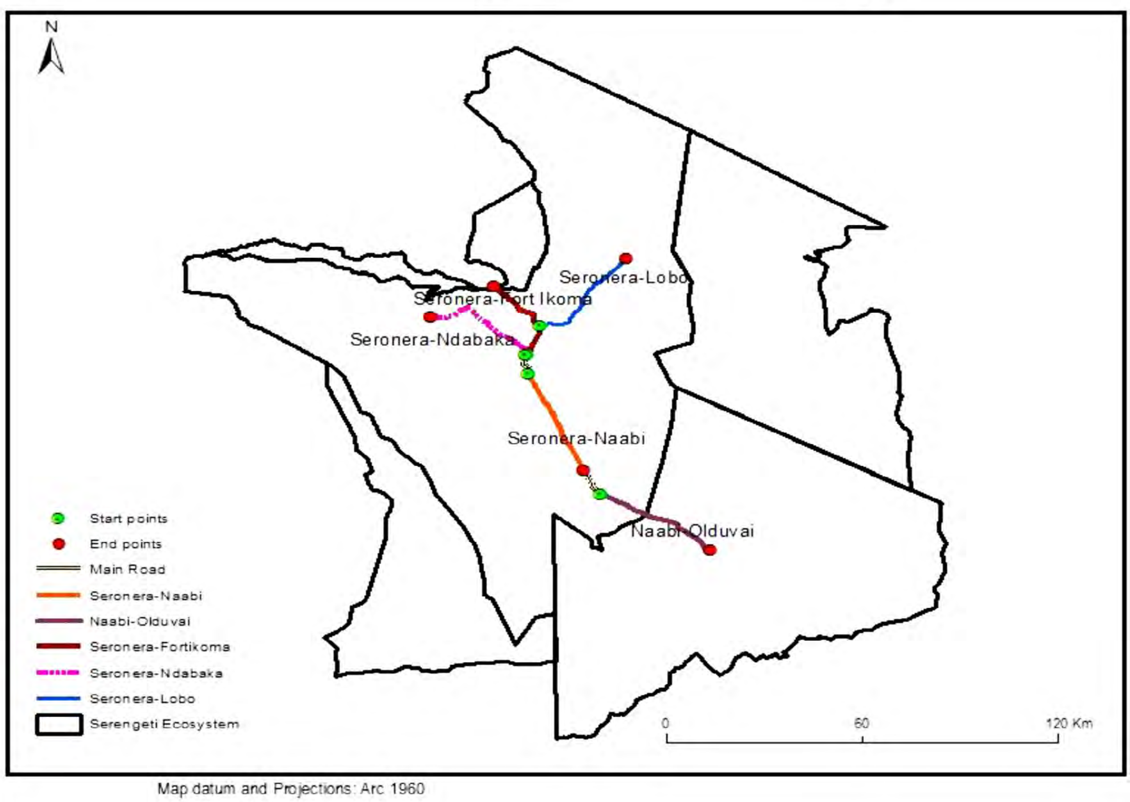

Fig.1. The study area map showing the surveyed transects

Data collection

The survey was conducted in wet (March-April 2015) and dry (July-August 2015) seasons. In each day there were two sampling sessions, the morning session (07:30-11:30) and the afternoon (14:00-18:00). The survey was conducted along five transects, each with a length of 40 km and included the main roads in the Serengeti ecosystem, namely Naabi-Oldupai, Seronera-Naabi, Seronera-Fort Ikoma, Seronera-Ndabaka and Seronera-Lobo (Fig. 1).

At the beginning of the transect of each sampling session, the vehicle odometer was set to zero and recorded transect name, GPS location, time, transect length, road width, date, season and names of recorders. The vehicle was then driven at a speed of about 20km/hr or below 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 to locate any carcass or injured animals. Each encountered carcass or injured animal species was identified and the GPS location recorded. Additional information including the time, condition of carcass/injured animal(s), number, estimated age class (adults, sub adults, juveniles), sex and habitat type were recorded in a standard data sheet. After collecting all required data, the carcass, was removed from the road to avoid double counting.

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. Furthermore, t-test was used to compare the number of killed animals between sessions (morning & afternoon), transects (Seronera-Naabi, Naabi-Olduvai, Seronera-Fortikoma, Seronera-Lobo, and Seronera-Ndabaka), seasons (dry and high tourist season & wetand low tourist season) and habitat type (grassland, woodland, wooded grassland, riverine & bushland).

We also conducted a Chi-square Test to test whether there was any statistical significance differences between categorical data representing the total number of male and female road kills recorded at different sessions. To evaluate which animal category (birds & mammals) as our dependent variable was mostly killed in relation to session, transect name, season, road and habitat as independent variables, we conducted a logistic regression analysis with the method enter to evaluate the relationship between tested variables. All tests reported at level of $p \leq 0.05$ were considered statistically significant.

RESULTS

Status and vulnerability of wildlife roadkill

Our results revealed that a total of 51 animals were observed killed along the roads transect, comprising of 26 species including 7 mammals and 19 birds (Table 1). Birds were the more killed species (60.78%, n = 31) followed with mammal species (39.22%, n = 20; Table1).

Spatial-temporal patterns of wildlife road kill

Results showed that animal species killed along the roads did not differed significantly between transects (Chi-test: $x^2 = 4.39$, df = 4, p = 0.355). Despite that Seronera-Fort Ikoma road transect had more road kill (35.3%, n = 18), followed by Seronera-Ndabaka transect (23.5%, n = 12), Seronera-Naabi transect (21.6%, n = 11), Seronera-Lobo transect (13.7 %, n = 7) and the Naabi- Olduvai transect (5.9%, n = 3; Table, 1). A binary logistic regression analysis based on animal category (birds & mammals)

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

Species type	Family	Common name	Scientific name	Road transect						
				Seronera - Naabi	Seronera - Ndabaka	Seronera - Lobo	Seronera - Fortikoma	Seronera - Olduvai	Total killed	% killed
Birds	Alaudidae	Fisher's sparrow-lark	*Eremopterix leucopoenia*	0	0	0	0	1	1	1.96
		Red-capped lark	*Calandrella cinerea*	0	0	0	0	1	1	1.96
		Flappet lark	*Mirafra rufocinnamomea*	0	1	0	1	0	2	3.92
	Cisticolidae	Croaking cisticola	*Cisticola natelensis*	1	0	0	0	0	1	1.96
		Rattling cisticola	*Cisticola chiniana*	0	1	0	0	0	1	1.96
	Columbidae	Ring-necked dove	*Streptopelia capicola*	1	0	0	1	0	2	3.92
	Coraciidae	Lilac-breasted roller	*Coracias caudata*	0	1	0	1	0	2	3.92
	Estrildidae	Red-cheeked cordon-bleu	*Uraeginthus bengalus*	0	0	0	1	0	1	1.96
	Laniidae	Grey-backed fiscal	*Lanius excubitoroides*	0	1	0	0	1	2	3.92
	Malaconotidae	Brown-crowned tchagra	*Tchagra australis*	0	0	0	1	0	1	1.96
	Numididae	Helmeted guinea fowl	*Numida meleagris*	1	0	2	3	0	6	11.76
	Phasianidae	Crested francolin	*Francolinussephaena*	0	0	0	1	0	1	1.96
		Coqui francolin	*Francolinus coqui*	0	2	0	0	0	2	3.92
		Grey-breasted spurfowl	*Pternistis rufopictus*	0	1	0	0	0	1	1.96
	Ploceidae	Speckle-fronted weaver	*Sporopipes frontalis*	0	0	0	1	0	1	1.96
		Grey-capped social weaver	*Pseudonigrita arnaudi*	0	0	0	1	0	1	1.96
	Pteroclidae	Chestnut-bellied sandgrouse	*Pterocles exustus*	0	1	1	0	0	2	3.92
	Sagittariidae	Secretary bird	*Sagittarius serpentarius*	2	0	0	0	0	2	3.92
	Sturnidae	Superb starling	*Lamprotornis superbus*	0	0	0	1	0	1	1.96

Mammals										
	Suidae	Warthog	*Phacochoerus africanus*	1	0	0	0	0	1	1.96
	Bovidae	Thomson gazelles	*Gazella thomsonii*	3	1	1	0	0	5	9.80
		Diki-dik	*Madoqua kirkii*	0	0	1	0	0	1	1.96
		Wildebeests	*Connochaetes taurinus*	0	0	0	2	0	2	3.92
	Leporidae	African hare	*Lepus capensis*	1	3	2	3	0	9	17.65
	Canidae	Bat-eared fox	*Otocyon megalotis*	0	0	0	1	0	1	1.96
		Silver-backed jackal	*Canis mesomelas*	1	0	0	0	0	1	1.96
		Total		**6**	**4**	**4**	**6**	**0**	**20**	**39.22**
		Grand total		**11**	**12**	**7**	**18**	**3**	**51**	**100**

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 species was mostly killed in the area (Logistic regression: x^2= 13.790, df= 6, p= 0.032, Negelkerke R^2= 0.321). Transect type, season, location and habitat did not add any significant value in explaining this variation.

More animal kills were recorded during the morning (70.6 %, n = 36) than the afternoon (29.4 %, n = 15) session and their differences were not statistically significant (Chi-test: x^2 = 3.29, df = 1, p = 0.070). Moreover, more males (56%, n = 5) than females (44%, n = 4) were found killed during the morning than afternoon session and their differences were statistically significant (Chi-test: x^2= 5.6, df = 1, p = 0.018). From the sex identified associating with wildlife road kill, males were strongly positive related to road killed during the morning session (r= 0.791, n = 9, p = 0.011). In addition, more birds (52.8%, n = 19) than mammals (47.2%, n = 17) were recorded during the morning session.

Generally, wildlife roadkill occurred more during dry (July to August) and during high tourist season (64.7%, n = 33) than in wet (March to April) and during low tourist season (35.3%, n = 18) but their differences were not statistically significant (Chi-test: x^2 = 3.11, df = 1, p = 0.078). Moreover, more bird road kill were recorded in the dry (74.2%, n = 23) than in the wet season (25.8%, n = 8) than mammals (50.0%, n = 10). However, mammals road kill were recorded more in the wet season (55.6%, n = 10) than birds (44.4%, n = 8). African hares (*Lepuscapensis*) (17.7 %, n = 9,) were more killed along the road than other mammals (Table 1). On birds, helmeted guinea fowl (*Numidameleagris*) (11.8%, n = 6) were the major victims of wildlife road kills in the area (Table 1). Generally, more adults wildlife species (92.2%, n =51) than sub adults (5.9%, n = 51,) and juveniles (n = 51, 1.9 %) were found killed in the area (T-test: t = 57.435, df = 50, p < 0.001). Specifically, adult birds (90.3%, n = 31) were more killed than sub adults (6.5%) and juveniles (3.2%). A similar pattern was found on mammals; with adults (95.0%, n = 20) more killed than sub adults (5.0%, n = 20) and no juvenile animals were found killed.

The overall wildlife road kill occurrence did not differed statistically significantly between habitat types (Chi-test: x^2 = 3.43, df = 3, p = 0.329). However, highest frequency of road kill was recorded more in wooded grassland (39.2%, n = 51) of the Seronera – Lobo transect compared to other habitat types such as grassland (33.3%), woodland (21.6%) and bushland (5.9%).

The wildlife roadkill differed significantly between small (78.4%, n = 40) and medium to large bodied (21.6%, n = 11) animals in the area (Chi-test: x^2 = 21.73, df = 1, p < 0.001). More small bodied animals were found killed in the wooded grassland habitat (85%, n = 17) than medium-large bodied animals which were more recorded on the grassland habitat (41.2%, n = 7).

DISCUSSION

Status and vulnerability of wildlife to road kills in Serengeti ecosystem

Previous study revealed that wildlife road kills was one of the visible impacts of roads on animal populations inside of protected areas, with a wide range of taxonomic groups being killed every year (Underhill, 2002). Our findings have demonstrated and are in support Underhill (2002) and the observed variations of wildlife kills along the roads in terms of body size and time show that animals were vulnerable to the presence of roads in the area. Since, it was observed that more animals with small than medium to large bodied size were found killed in the wooded grassland area and this supports our first hypothesis that animals with small body (like hares, rodents and birds) size would be more killed than those with medium to large larger body size, because they are probably more abundant (Barthelmess & Brooks, 20101) and frequently attempting to cross the road (Brockie *et al.*, 2009) and therefore increasing their chances of been hit by vehicles. Also, it concurs with those of the study by Kelleher (2015) which found that though more small bodied animals were killed by vehicles than medium to large ones, but their current estimates on the road kills are limited. This is probably because partly road kill rates are usually under estimated due to their low detectability, rapid removal by scavengers or deterioration/degradation by passing vehicles (Slater, 2002). Thus the actual impact of road mortality on population persistence for most species is unknown (Brockie *et al.*, 2009; Kelleher, 2015). Furthermore, according to Kelleher (2015), by not counting these small animals, much estimation has left out a massive portion of the total deaths. For example, in Brazil, 9 out of 10 of the animals were small - like birds, frogs or snakes (Kelleher, 2015).

Despite of the reported number in this study, the numbers of animal fatalities attributed to vehicle collisions are considered to be under estimates (Bishop & Brogan, 2013). Hence, this finding supports that the theory that gravel roads are a major cause of wildlife mortality in protected areas and also that roads traversing through protected areas have adverse impact on wildlife (Bissonette & Kassar, 2008; da Cunha et al., 2010; Santos *et al.*, 2011; Selvan *et al.*, 2012). In addition, it supports that road mortality is currently one of the main issues in the protection of animals (Orłowski, 2005).

Moreover, more birds than mammals were killed in the area. Birds were killed more presumably because they were attracted to forage at the edge habitats where predation activities as well as vehicle collisions were higher (Kociolek & Clevenger, 2009). Our findings thus concur with those of the study by Orłowski (2005), which reported that more birds were highly affected by the negative impact of roads. Also, our findings support the previous study by Forman & Alexander (1998) who reported that birds were more attracted to roads because of spilled grain, road side plants and insects, water availability along the road salt or dead animals and thus increased their chances of being hit by vehicles.

Therefore, these results increase our understanding on the species or wildlife communities that are more vulnerable to road-kill, such as helmeted guinea fowls (*Numidameleagris*) on the birds' side and the African hares (*Lepuscapensis*) on the mammals' side. Furthermore, increased road kill of helmeted guinea fowl could be attributed to their activeness during the morning hours (Njiforti, 1997) which might have increased their feeding activities on seeds and dead insects as road kill that might be available along roads and hence collide with passing vehicles. During this study we also encountered the mortality of endangered bird species listed by IUCN as vulnerable (IUCN, 2016), especially the secretary bird (*Sagittarius serpentarius*). The bird is a vertebrate feeder possibly using road surfaces as hunting substrate for capturing preys or taking advantage of presence of road kill, as a result exposes to vehicle collision. The study has also revealed existence of a road kill mortality of grey-breasted spurfowl (*Pternistis rufopictus*) along roads the endemic species to the Serengeti. Though previous studies have estimated that "avian roadkill" totals were in the millions in the United Kingdom, Europe, Scandinavia, and the USA (Bishop & Brogan, 2013), but few studies have reported this scenario in the Serengeti ecosystem (Nkwabi *et al*. 2018). On the other hand, few mammals were recorded killed, probably because mammals have to cover higher distances to satisfy their water requirements and thus they become less abundant along the road verge. Similar results have been reported by Orłowski(2005).

However, in this study, we were able to identify the hot spots of wildlife road kills, as most of these kills were concentrated on the woodland area of the Seronera-Ndabaka and Seronera-FortIkoma transects found in the north-western part of the ecosystem. The findings concur with the study by Magnus *et al.* (2004) which revealed that most of the wildlife mortality that occurred on roads was constrained to small and specific sections of roads. Also, this finding was supported with previous study by Nkwabi *et al.* (2018) which reported that more road kills were observed in the wooded grassland. There are several reasons that could be involved for this to happen. One of them probably could be that the area receives more rainfall (Holdo *et al*., 2009, Huffman, 2017) which facilitated forage abundance and quality availability in the area and thus attracted as well as increased the presence of many other animals,an indication that attraction to food and water was the main reason for the victims to road kill. This is also supported by the study by Magnus *et al*. (2004) which reported that animals were attracted to roads because of grass and water in roadside ditches, which could often remain well into dry season, when little food or water was available elsewhere and also existing animal carcasses resulting from road kill. Also, Njiforti, (1997) reported that Vachellia species generally grow only on soil that is partially flooded during the rainy season, and thus such habitat will still have more nutritious food during the dry season and be more attractive to many animals such as in our case the helmeted guinea fowls and the African hares when the other habitat types have become dry and poor. In addition, it concurs with previous study which reported that birds were attracted to roads as a location of concentrated resources, especially food (i.e. small mammals and carrion, insects and worms) (Bishop & Brogan, 2013). The other reason could be that both the helmeted guinea fowl and African hare were abundant during the dry period in the area compared to other areas (Williams *et al*. 2019). Since, previous studies had revealed that the wildlife species more hit by vehicles were usually those which were more abundant in the area (Freitas *et al*., 2013). Also, the study by Magnus et al. (2004) reported that the animals were often present on roads simply through the action of crossing to the other side and by doing so they become victims of road kill. Usually wildlife cross roads to gain access to crops, pasture, water or territories (and in other countries, crossing roads is part of a regular migration route for some animals). Our results also concur with previous findings which reported that wildlife road kills usually do not occur randomly but are spatially clustered (Magnus *et al*., 2004). In addition, less animals were recorded killed in the Seronera-Naabi and Naabi-Olduvai transects in the southern Serengeti plains probably because this area received less an annual rainfall of < 600mm (Sinclair *et al*., 2002; Homewood *et al*., 2004) and therefore making it relatively drier, thus caused road verge to be less attractive to most animals.

Therefore, our finding supported what previous studies had reported that most of affected victims (i.e. Helmeted guinea fowl and African hares in our case) were attracted to spilled grain, road side plants and insects (Forman & Alexander, 1998; Freitas *et al.*, 2013). Moreover, since roadside trees, hedgerows, and other features might cause birds to fly higher across roads to avoid collisions with vehicles but for ground living birds like helmeted guinea fowls it would be impossible for them to fly higher and thus why were more susceptible to road kill (Bishop & Brogan, 2013). Other mammals less frequently recorded killed were bat-eared fox (*Otocyonmegalotis*) and silver backed jackal (*Canismesomelas*). These probably were killed while scavenging on carcasses on the road (Vidal–Vallés *et al*., 2018). According to Vidal–Vallés *et al*. (2018) scavengers or species with opportunistic feeding habits –such as badgers and martens or vultures and kites– may also have increased possibility of becoming road kill when they are attracted to corpses on the road. In addition, this could also be attributed to inability of those mammals to escape from over speeding vehicles, corroborating with other researchers (Bouchard et al., 2009; Chambers *et al.*, 2010; Lima *et al*., 2015).

Spatial-temporal patterns of wildlife road kill

Our findings further revealed that more wildlife species were recorded killed during the morning than afternoon session,which agreed with our suppositions. During that period more male animals were found killed than females in the Seronera-Ndabaka and Seronera-Fort Ikoma transects north-western part of the ecosystem. This finding concurs with that from the study by (Putmam, 1997), which reported that more male vertebrates have been implicated to road accidents. This happened probably because males were more active feeding during that time along the road verges and vehicles hit them as the result while passing.

Precisely more wildlife road kill occurred during dry season than in wet season reflecting the expected observed seasonal pattern (Dussault *et al*., 2006). In our case birds' road kill were more recorded during the dry season than mammals 'species supporting what previous studies have found that differences in composition and species abundance of road kill are related to season and to habitat selection (Kociolek& Clevenger, 2009; Griet *et al*., 2016; Vidal–Vallés *et al*., 2018). According to Vidal–Vallés *et al.* (2018), this period is linked to the first flights of inexperienced young (note that most species breed in spring, and in summer juveniles are dispersing), which might be affected to a greater extent by collisions. Moreover, it was equally easier for the birds to see approaching predators in open habitat than in habitat with dense vegetation cover. Our finding furthermore concur with those of the previous study by Bishop & Brogan(2013) which reported that presumably birds were at their breeding period in the area or were foraging, roosting, or nesting near roadsides which increases their collisions.

Furthermore, more adults' wildlife species were recorded killed in the area. Our finding concur with that from the study by Sosa & Schalk (2016) which reported that adult male snakes were at higher risk as they make large forays outside their home ranges in an effort to search formates which in turn, increases their likelihood of crossing a road and exposure to vehicular traffic. Also with the study by Bishop & Brogan (2013), which revealed that vehicle collisions, unlike predators, remove many healthy and mature breeding animals from populations. Moreover, Bishop & Brogan (2013) reported that higher mortality of adults and fledged birds from roadside habitats could create sink populations that can only persist through immigration. Moreover, presumably because of presence of roadside territories this seemed to be that males experienced difficulty in attracting and/or retaining mates because females would abandon the road zone, possibly due to high disturbance (Kociolek& Clevenger, 2009). Also, more adult males were recorded killed in the area probably due to their high numbers, confidence and inability to escape because of body weight compared to juveniles.

CONCLUSIONS AND RECOMMENDATIONS

This study confirmed that the existing gravel road network adversely impact a variety of wildlife species in the area by providing information on the wildlife numbers and species recorded killed. The data is valuable and timely, as it will enhance improvement of wildlife conservation at a time in which the road network is developed in the area. From these findings we therefore recommend that further investigation by done on the ecology and behavior of helmeted guinea fowls and African hares on the gravel road networks of Serengeti ecosystem. In addition, we encourage more studies of this type in the area. Moreover, decision makers, scientists and urban developers together, should work more closely when planning or improving a (new) road in order to minimize road kill impact. Scavengers are killed when they feed or look for food on the roads, we suggest road kill carcasses be removed from roads, verges and gutters as soon as possible to minimize the likelihood of collisions. Furthermore, we call for strengthening of fines, establishment of vehicle speed limit check points, installation of speed limit devices (e.g. solar powered cameras) and educating road users on the negative effects of roads on wildlife. Also, road signs for drivers should be reinforced in the areas of high road kill occurrence.

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KNOWLEDGE AND AWARENESS ON RHINO CALF PREDATION BY SPOTTED HYENAS IN THE NGORONGORO CONSERVATION AREA

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ABSTRACT

Calves of black rhino trail behind their mothers predisposing them to risks of attack by stalking predators. A total of 272 respondents were randomly selected and interviewed from 8 villages located in the Ngorongoro Conservation Area. Most of the interviewed wildlife rangers 87.5% had seen hyena attacking rhino calves and only 22.8% of the interviewed villagers had seen or witnessed spotted hyenas attacking black rhino calves. The reasons why hyena attacked rhino calves were hyenas have changed their behaviour from being scavengers to active hunters (53.1%), black rhinos do not provide enough protection to the calf after birth (15.6%) and the increase in the hyena population in the crater floor (18.8%). 69.6% of village respondents and 65.6% of the wildlife rangers suggested that translocation of spotted hyenas from the crater as an effective mitigation measure to control the predation of black rhino calves. Those who disagreed with the translocation suggested that a better mitigation method may be isolating the rhino calf by keeping them in a boma or fenced area together with the mother until the calf had grown enough to chase away predators.

Keywords: Black rhinoceros, knowledge and awareness, Ngorongoro Crater, rhino calve predation

INTRODUCTION

Black rhinos (*Diceros bicornis*) is a native species to eastern and southern Africa. The specie is highly threatened as a result of poaching; and have declined by 95% throughout their range (Metzger *et al*., 2007; Emslie, 2020). Because of this, the International Union for Conservation of Nature (IUCN) categorized as critically endangered species (IUCN, 2004). In this regard, the poor performance of black rhino population needs thorough investigation on factors that might be limiting population growth including genetic and demographic threats (Moehlman *et al*.,. 1996; Plotz & Linklater, 2009). The conservation challenges for black rhinoceros in Ngorongoro crater that need to be addressed include poaching, diseases, habitat destruction, depredation of calves and encroachment by the expanding human population as well as biological aspects (Walpole et al., 2001; Walpole, 2002; Fyumagwa & Nyahongo, 2010). Black rhinos are generally solitary with strong social bonds between a cow and calf, bulls have consort relationship with oestrus females while sub adults and young forms loose relationships with older of either sex (Tatman *et al*., 2000). The solitary nature makes it difficult for nursing females to protect the calves. Calves of black rhino trail behind thier mothers predisposing them to a risk of attack by a stalking predator.

Recently, there has been a challenge relating to the predation of rhino calves and juveniles by spotted hyena (*Crocuta crocuta*). The reasons for this is yet to be established but the high density of spotted hyena in the crater is thought to be contributing to the challenge. In 1960s, hyena population was estimated at 385 and declined to 139 in 2000, a year, which had severe drought that caused mass mortality of herbivores in the crater, and one could expect the number to increase due to plenty of carcasses contrary to what is reported (Estes *et al*., 2006). Honer et al. (2002) and Estes *et al*. (2006) speculated that the reasons for the decline in hyena population could be associated with decline in main prey species including plain zebra and wildebeest. In 2006, hyena population ranged between 171 and 347, and recently reported 550 individuals (Honer, 2016). Spotted hyena is termed generalist predator, efficient hunter and also scavenger (Honer *et al*., 2002; Hayward, 2006). According to Tatman et al. (2000) and Frame (1980), black rhino prefers densely vegetated habitats, which mostly attributed to food and water availability. Black rhino preference for dense habitat as calving areas might be the reason for falling victim to predation. It is not known why spotted hyenas prey on rhino calves despite the fact that the crater has significant number of herbivores including but not limited to plain zebra (*Equus quagga*), wildebeest (*Connochaetes taurinus*), gazelles and others.

The increase in hyena population by more than two-fold is not well understood, requiring some investigation. In order to establish a research-based solution to this challenge we conducted a survey in the surrounding villages along a gradient from the Ngorongoro crater rim. The study aimed at assessing the knowledge of the people on the rhinos calve depredation by spotted hyena, their perception on the suitability of the crater for the current rhino conservation and compare it retrospectively to the situation about five decades ago. Thus, the study aims to generate information to help guide NCAA to make appropriate conservation actions to help conservation of the endangered black rhinoceros. The main objective was to assess the magnitude of predation of black rhino calves and propose effective mitigation measures in ensuring sustainable conservation of this species in the Ngorongoro Crater and the Serengeti ecosystem at large. Specific objectives were to determine the frequency of encountering black rhinos and spotted hyena in the villages; assess knowledge on rhino calf predation by spotted hyenas; determine knowledge on whether spotted hyenas of the crater ascend out; inquire on management intervention and other anthropogenic activities that might have influenced increase of hyena population in the crater floor and to assess the livestock depredation by spotted hyenas.

MATERIALS AND METHODS

Study area

The Ngorongoro Conservation Area (NCA) measures about 8,292 km^2 and adjoins the South-eastern edge of the Serengeti National Park (SNP) between 2°30’ to 3°30’S and 34°50’ to 35°55’E. NCA was established in 1959 as the multiple land use protected area where wildlife and other natural resources are protected, and the interest of the resident pastoral communities therein promoted (Estes *et al*., 2006). The area is also recognized by the United Nations Scientific and Cultural Organization (UNESCO) as the World Heritage Site and Biosphere Reserve, which is part of the Serengeti ecosystem. Ngorongoro crater is one of the few protected areas in Africa where black rhinos can be easily spotted in the open grassland of the crater floor (Fig. 1).

Eight villages were selected based on the relative distance from the crater rim. Seven of the villages (Ngoile, Meshili, Oloirobi, Kayapis, Mokilal, Irkeepusi, and Endulen) were relatively close to the crater rim (1-20 km), which are within the distance that spotted hyenas can commute within a day (Kolowski & Holekamp, 2006). The last village (Kakesio village in Kakesio ward) was beyond an average distance for hyena to commute within a day (>60 km) and this village acted as a control site (Fig. 1). The socio-ecology behaviour results to the interactions between livestock and wild animals which results to conflicts by livestock owners when their livestock get killed by carnivores, as well as diseases transmissions between livestock and wild animals. The Maasai livestock are kept in traditional kraal or bomas, which is embraced by a circular thorny fence, with the family huts enclosed in an inner fence with livestock kept and guarded at night, inside this enclosure (Muchiru *et al*., 2009). 'Bomas' are constructed using thorny bushes in order to prevent livestock predation by large carnivores such as lion (Panthera leo), leopard (Panthera pardus) and spotted hyaena (*Crocuta crocuta).*

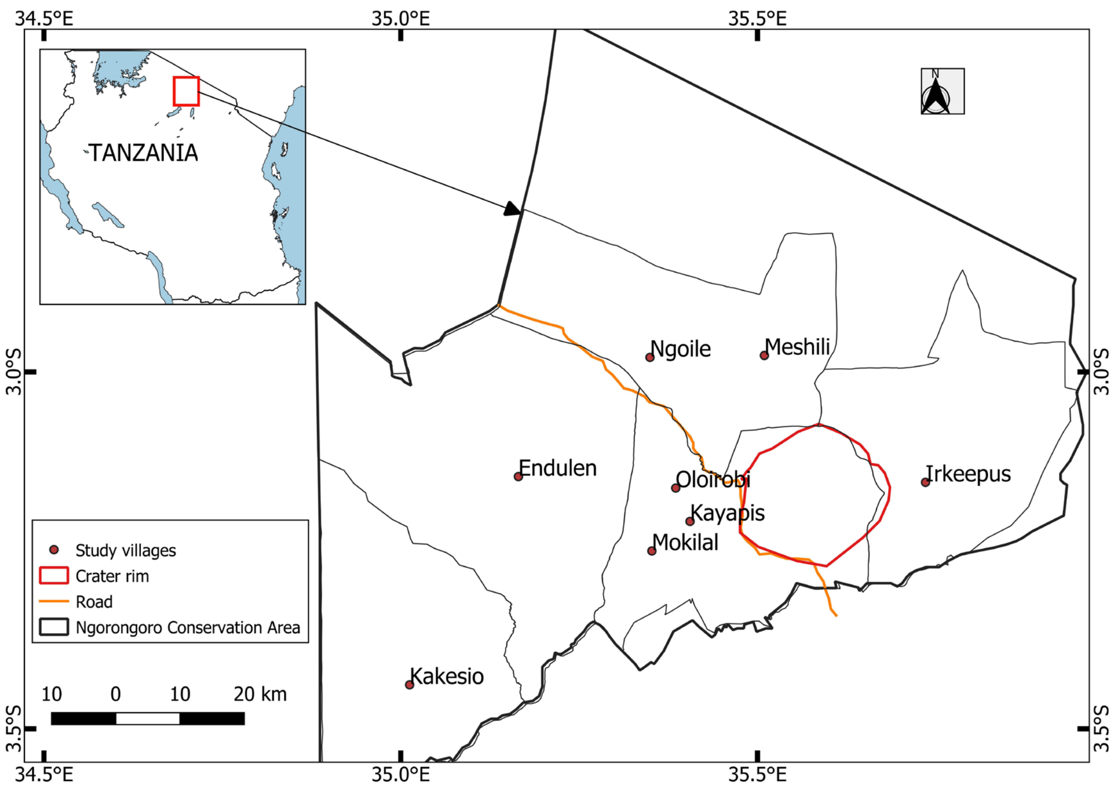

Fig. 1. Map of NCA showing selected study villages in red dots

Data collection

The data collection included administering household questionnaires, key informant interviews (N = 272) and focused group discussions. Key informant interviews were purposively directed to NCAA staff and researchers, and focused group discussions were conducted to village leaders and selected sub-village representative in each of the study village. The villages were selected with the main criterion that the village should be located in the crater rim (Mokilal, Oloirobi, Irkeepus and Kayapis) medium distance to crater rim (Meshili and Ngoile) and far distant village from the crater rim (Kakesio and Endulen). We assumed that people from the village closest to the crater rim have incurred greater losses of livestock due to depredation by spotted hyena and have greater knowledge and awareness of rhino calf depredation by the spotted hyena.

Prior to the interview, the main purpose of the study was explained to the village executive officer or chairman. Permission for conducting interviews was then granted. For this study, the household was regarded as a sampling unit. Respondents above 18 years old were randomly selected for interview. A total of 272 respondents were randomly obtained and interviewed from 8 villages. Any member of the house who was 18 years old or above was interviewed during the survey if the head of the family or wife was not present. The purpose of this was to reduce the biases in the selection of households and to ensure that the sample was representative. The interview was conducted under the assistance of local translators. The information that was recorded included the socio-demographic variables (tribe, age, gender, education level, occupation and wealth) and the knowledge depredation of rhino calves by spotted hyena, livestock depredation, season and time of attack. The questionnaires were prepared in the English language but were translated into Swahili language during the interview.

DATA ANALYSIS

Questionnaire were coded and analyzed using Statistical Package of Social Science (SPSS version 24, NY, USA). Descriptive statistics was used to generate means and percentages for comparison purposes. Chi-square tests was used to determine the significant differences among the research results. Where data was not normally distributed, non-parametric statistics test was used. Histogram and pi-chart were used for illustration in comparing the differences. The significance level was set at $P < 0.05$.

RESULTS

Frequency of encountering black rhinos and spotted hyena in the villages

The Household questionnaire survey in eight study villages in NCA showed that more than half (57.7%) of the 272 respondents had knowledge and had seen black rhinos in their areas at different times of the year. The details for the observation are that about 40.4% had seen rhinos during the last less than 10 years, 7.4% during 10-19 years ago, 4.4% during 20-29 years ago, 5.1% during 30-39 years ago, and only 1.1% more than 40 years ago, while 41.6% of the respondents had never seen black rhinos in their village. However, of the total respondents, 76.8% (n = 209) replied that it is not common to encounter black rhinos in their village. Furthermore, 44.9% of the respondents commented that the population of this species has decreased compared to the 1970's. Unlike black rhinos, almost all (98.1%, n = 272) had seen hyena in the village, and 76.5% of them had seen or heard sounds of hyenas every day in the village, 83.1% stated that the hyena population of has increased compared to 40 years ago

(1970's). The frequency of encountering black rhinos differed statistically significant between the wildlife rangers of NCA and the villagers as almost all, 93.6% (n = 30) of the rangers had seen or spotted black rhino while only 52.9% (n = 240) of the villagers had spotted black rhinos in their vicinity (χ^2 = 19.29, df = 1, p = 0.0001).

Knowledge on rhino calf predation by spotted hyenas

Of the total 272 respondents, only 62 (22.8%) had seen or witnessed hyenas attacking black rhino calves, but all were observations in the crater and not in their village (Figure 4). A total of 28 wildlife rangers (87.5%; n = 32) had seen hyena attacking rhino calves, while only 32 (14.2%; n = 240) of villagers had observed such hyena attacks, a statistically significantly difference (χ^2 = 86.28, df = 1, p = 0.0001). When asked for the reasons why hyena attacked rhino calves, 53.1% stated that hyenas have changed their behaviour from being scavengers to hunters 15.6% stated that black rhinos do not provide enough protection to the calf after birth, thus, they become easy prey to hyenas, and 18.8% associated this increase with the increase in the hyena population in the crater floor. About 167 out of 272 village respondents (69.6 %) and 21 of the wildlife rangers (65.6%) respectively, accepted the idea that translocation of hyenas from the crater can be an effective mitigation measure to control the predation of black rhino calves. Those who disagreed with the translocation suggested that a better mitigation method may be isolating the rhino calf by keeping them in a boma or fenced area together with the mother until the calf had grown enough to chase away predators. A very high proportion of both villagers and wildlife rangers (96.7% and 100.0% respectively) performed a positive perception towards black rhino conservation and added that this species is important for tourist attractions to the Ngorongoro crater. However, between villagers and wildlife rangers there was a statistically significant difference in their attitude towards spotted hyena as only 11.7% (n = 240) of the villagers performed a positive attitude while the majority of the wildlife rangers 93.8% (n = 32) performed a positive attitude towards the spotted hyena (χ^2 = 113.4, df = 2, p = 0.0001). Thus, most villagers considered spotted hyena as worthless and destructive to their livestock.

Knowledge on whether spotted hyenas of the crater ascend out

Of the 272 respondents, 50.7% claimed that hyenas are not ascending out of the crater, while, 46.7% claimed that hyena ascended out of the crater, while only 2.7% of the respondents had no knowledge about hyena movements. The reasons given for hyena not to ascend out from the crater included; hyenas were afraid of being killed by Maasai (19.9%), there are enough prey and carcasses in the crater (10.7%), provision of buffalo carcasses by NCAA in early 2000's in the crater influenced them not to ascend out of crater (12.5%), while 9.9% did not know and 47.1% remained silent to this question.

Livestock depredations by hyenas

Most (85.3%, n = 272) of the respondents reported that the incidences of the hyena attacks on livestock have currently increased compared to 40 years ago in the villages. Reasons given by the respondents for the increase in depredation incidents included enough prey and livestock carcasses which contributed to the increase in hyena breeding success (44.2%), Maasai morani are not currently killing hyenas (23.1%), and that hyena population has increased due to strengthened protections (32.7%). Most of the livestock attacks 54.8% of the livestock attack occurred during nighttime, followed by evening (17.3%), afternoon (12.5%), while a few attacks (1.1%) occurred during the morning, while 9.2% claimed that attacks occurred both during afternoon and night whereas 5.1% of the respondents did not know. The livestock types killed included sheep, goats, donkey and cattle.

Focus group discussion

The focus group discussion had about 8 guiding questions for interviewers to ask the participants. The questions included existence of hyenas in the villages, existence of black rhinos in the villages or adjacent areas, rhino calve predation incidences, livestock depredation incidences by hyenas, possible mitigation measures to minimize depredation, control measures to avoid livestock depredation and rhino calve predation, importance of rhino conservation and known rhino corridors from indigenous knowledge. The details for the response from each question is outlined here under;

Existence of hyenas in the villages

In general, the knowledge of the existence of hyenas within village lands was found to be higher (above 90%) among maasai pastoralists in 5 villages, however in Kakesio a slightly lower (40%) of maasai did not have the knowledge about hyenas within the village land (Table 1). The participants gave various factors that were considered to exacerbate the perceived increase in hyenas in their villages including; hyenas have high reproductive rates/short gestation time; effective law enforcement by NCAA; community understanding on the importance of conservation, therefore, there is less retaliatory killing incidences of carnivores; effective vaccination programs to domestic dogs has reduced diseases that can kill hyenas like rabies; hyenas are efficient scavengers and hunters and have communal feeding; the NCA has high number of prey species including livestock and the NCA has dense forests that provide good cover for the hyenas close to human settlements.

Table 1: The knowledge on the existence of hyenas, rhinos in village areas and rhino calve predation by spotted hyenas

Village	Number of participants	Knowledge of the existence of hyenas in village lands		Knowledge of the existence of hyenas in village lands		Rhino calves predation incidences	
		% with	% without	% with	% without	% witnessed	% Not witnessed
Mokilal	12	98	2	100	0	0	100
Meshili	12	98	2	60	40	10	90
Endulen	12	98	2	100	0	0	100
Ngoile	12	96	4	65	35	0	100
Kakesio	12	60	40	60	40	0	100
Nainokanoka	12	95	4	90	10	0	100

Existence of black rhinos in the village

The knowledge on the existence of rhinos in village lands ranged from 60 -100% in all villages. The FGD was composed of different age classes, therefore, those who were above 50 years old were more knowledgeable on the presence of rhinos within the villages in the past when they were growing up and looking after livestock (Table 1). Out of the 12 participants in Meshili and Ngoile villages 40% were youths and thus did not experience rhino in their village lands. However, they knew on the existence of rhinos inside the crater. Due to absence of rhinos adjacent to the villages compared to the past five decades, it was concluded that the population of rhinos is decreasing. The respondents mentioned that the reasons for their decrease were mentioned as follows; few numbers of male rhinos affect breeding performance; high poaching pressure decimated rhinos near villages and Confinement of rhinos inside the crater by NCAA affects dispersal of rhinos outside the crater and be noticed adjacent to villages.

Rhino calves predation incidences

During the discussion it was noted that only in Meshili village where 10% respondents had witnessed hyenas kill and prey on rhino calves (Table 1). This was a confession of those who were youth in 1960's. Currently rhinos are rarely seen and therefore, difficult to ascertain this observation. What people understood is that rhino mothers are poor in defending their young by leaving them behind while walking or leave their calves alone in the bush and move long distances to forage. Considering on the experience on livestock that are accidentally left behind in the bush, they concluded that it is possible for rhino calves that are left behind ending up being eaten by hyenas.

Livestock depredation incidences by hyenas

From the FGD discussions, it was understood that hyena depredatory incidences took place both inside the bomas at night and at daytime on grazing lands (Table 2). Most of the attacks inside the bomas occurred at night when people have slept. Hyenas have developed behavioral change whereby now they break boma walls using teeth, an observation which was not experienced in the past. Once the hyena enters the boma it frustrates the livestock resulting to stampede and breaking the boma walls and became easily depreciated. In grazing lands attacks happens anytime especially in dense woodlands when the herds are scattered or when few individuals stray and remain behind after grazing.

Table 2: Ideal environment for livestock depredation

S/N	Village name	Where do livestock depredation occur?
1	Mokilal	Both inside the bomas and grazing lands
2	Meshili	Inside the bomas
3	Endulen	Grazing lands
4	Ngoile	Both inside the bomas and grazing lands
5	Kakesio	Both inside the bomas and grazing lands
6	Nainokanoka	Both inside the bomas and grazing lands

Mitigation measures to minimize depredation

The respondents mentioned that when depredation incidences occur different measures are taken including reporting to NCAA, Village Executives Officers and to hyena researchers. However, among visited villages the incidences of livestock attack varied as shown in table 3 below.

Table 3: Time of livestock attack/predation and measures taken

S/N	Village	Time of attack	Measures taken
1	Mokilal	Night time	Report to NCAA
2	Meshili	Night time	Boma re-enforcing using thorns, Solar lights, guarding with dogs
3	Endulen	Anytime	Boma re-enforcing using thorns, solar lights and dogs
4	Ngoile	Anytime	Report to NCAA, Village officers, researchers, boma re-enforcement using thorns, dogs and solar lights
5	Kakesio	Anytime	Report to NCAA
6	Nainokanoka	Anytime	Trap and release them at Ndutu area and report to NCAA

Recommended control measures to avoid livestock depredation and rhino calf's predation

During the discussion on possible control measures for livestock depredation and rhino calf's predation, several options were raised by respondents but varied from village to another (Table 4). The possible measures were ranked, and it was recommended that in order to reduce hyena predatory incidences both for livestock as well as to rhino calves the following should be done.

Table 4: Possible control measures to avoid rhino calf's predation

S/N	Village	Measures
1	Mokilal	Confine rhino calves in cages/fences, provide continuous surveillance for newborn calves (24/7) until can defend themselves from predators, culling of hyenas and re-enforce bomas using chain-link
2	Meshili	Introduce fences on calves, culling of hyenas, re-enforce bomas using chain-link and provision of solar light
3	Endulen	Provide continuous (24/7) surveillance for newborn calves, re-enforce bomas using chain-link
4	Ngoile	Provide continuous (24/7) surveillance for newborn calves, re-enforce bomas using chain-link with concrete, use contraceptives for birth control of hyenas, regular boma repairs
5	Kakesio	Provide continuous (24/7) surveillance for newborn calves, compensation for depredation and human attacks and translocation of excess hyenas
6	Nainokanoka	Provide continuous (24/7) surveillance for newborn calves, compensation, culling of hyenas, translocation and re-enforce bomas using chain-link, create hyena free zones

Importance of rhino conservation

Generally, it was noted that the attitudes towards rhino conservation is positive as perceived as an attraction to tourists and thus, source of income and social development (Table 5).

Table 5: Importance of rhinos to maasai livelihoods

S/N	Village	Benefits of conserving rhino
1	Mokilal	Source of income/tourism attraction
2	Meshili	Source of income to the pastoral council, future inheritance
3	Endulen	Tourist attraction, development project such as schools
4	Ngoile	Tourist attraction and building schools
5	Kakesio	Tourism attraction and employment
6	Nainokanoka	Tourism attraction, employment, future inheritance, income to the council, rhino dung cure high fever and epileptic fits (“**degedege”**)

Rhino corridors from indigenous knowledge

The results from FGD show that majority of participants were aware of rhino corridors in their village lands or nearby areas (Table 6). It was only at Mokilal where participants were not aware of the presence of rhino corridors in their village land. The major concern from participants was that the NCAA drives back into the crater all rhinos that are trying to use these corridors. Some of the corridors are protected by rangers and therefore, participants urged NCAA to protect all corridors and allow rhinos to use them as it was before.

Table 6: Rhino corridors in selected study villages

S/N	Village name	Corridor name
1	Mokilal	All participants in this village were not aware of rhino corridors in their village
2	Meshili	Alayaani-Loomunyi and between Olduvai river- Serengeti
3	Endulen	Mokilal, Embarway, Ngiloriti and Orbili Lyamani
4	Ngoile	Eluanie, endepes, makasen and engutotosumbati
5	Kakesio	Engawagani
6	Nainokanoka	Londroto (inside the crater), Layanai (Olmoti crater), Ngskini (Olmoti crater), Engutotosumbati and Ebukoi

DISCUSSIONS

The response from resident pastoralists indicates that hyena population in community areas has increased compared to the past. This observation can be explained to be associated with increased livestock carcass availability in community areas due to frequent mortality from starvation. Livestock mortality from starvation due to prolonged drought exacerbated by overstocking has been an annual event since 2000. Presence of unattended livestock carcasses in community areas has probably influenced hyenas to move from the crater and elsewhere as far as Serengeti and live near bomas where there is easy prey. The assumption is supported by observation from Honer *et al.* (2002) and Estes *et al.* (2006) who reported decline in hyena population in the crater from over 350 in the 1960’s down to 139 in 2000. However, these authors associated it to the decline in prey species in the crater. Almost every household in the pastoral communities has experienced livestock depredation by hyenas corroborating with the report that hyena population has increased in community areas.

The increase in hyena population to a large extent is emanating from anthropogenic activities of resident pastoralists. Firstly, nomadic pastoralism which encourage overstocking results in annual high livestock mortality during dry season from starvation due to overgrazing, which is also complimented by secondary diseases in nutritionally stressed animals. Secondly, keeping livestock in temporary kraals at night covered with thorny acacia tree branches provide an easy prey to carnivores including hyenas, lions and leopards. Thirdly, maasai pastoralists do not dispose livestock carcasses when are in poor condition by burying or burning and leave to scavengers to feed on.

Presence of livestock carcasses in community areas almost annually from 2000 to date has influenced spotted hyenas to establish new dens near pastoralists' settlements, increased frequency of commuting phenomenon from elsewhere including crater and Serengeti National park to maasai bomas to attend livestock carcasses. In addition to that, availability of food for hyenas from dead livestock and easy access to livestock in kraals has enhanced the reproductive efficiency leading to increased hyena population. To some extent even the decline in hyena population in the crater in 2000, which was a very dry year can partly be speculated that probably many of them took a refuge into communities where there was plenty of livestock carcasses that died from starvation and secondary infections.

In order to minimize the current high level of human-carnivore conflict, some concerted effort must be undertaken including keeping few improved livestock and constructing permanent livestock kraals using chain link, which has proved to be very effective in preventing livestock attacks at night. In addition, during day time grazing livestock must be attended by adults in company with dogs as was established by Lyamuya *et al*. (2016). Livestock carcasses must also be attended by burning or burying to deny carrion to carnivores and hence discourage them to frequent maasai bomas at night, abandon dens near settlement and ultimately reduce number of carnivores roaming near settlements.

Although predation of rhino calves has been reported in the crater, very few resident pastoralists are aware of the problem. Exclusion to free access to the crater by pastoralists could be the reason and the few who had knowledge about rhino calf's predation were elders who had past experience when had free access and even settled in the crater. This observation suggests that probably the population trends of hyenas are increasing and is more likely that more hyaenas are found closer to crater than those villages at far distances. The lower knowledge of the maasai on the existence of hyenas in Kakesio may have been contributed probably by incidental killing of hyenas and or less prey species in their village lands.

CONCLUSIONS AND RECOMMENDATIONS

Hyena population has increased very much and apart from causing serious livestock depredation, it is also threatening population of small herbivores in the crater and rhinos. Therefore, it is recommended that a stakeholders meeting should be convened to deliberate on the imminent threat and come up with suggestions on how to handle such a serious problem to balance and sustain conservation of diversity of wildlife species in the crater and NCA in general. Understanding that hyena population has increased near settlements in NCA, some concerted efforts should be taken to provide education and awareness creation to pastoralists on the importance of building permanent and predator proof bomas using chain link as has been successfully demonstrated in Longido pastoral communities. Realizing that overstocking is the main root cause of annual high livestock mortality, which attracts wild carnivores close to settlements, measures should be taken to establish a limit of livestock numbers per household basing on available rangelands. In addition, pastoralists should be obliged to destroy livestock carcasses to discourage carnivores frequenting their bomas. Recognizing that part of livestock mortality is caused by diseases to nutritionally stressed animals, routine livestock vaccination should be enforced to ensure that outbreaks of diseases are controlled to minimize mortality and widespread carcasses in settlement areas, which has become a common observation during dry season.

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NUTRIENT RE-DISTRIBUTION FROM TERMITE MOUNDS IN A MIOMBO WOODLAND, TANZANIA

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ABSTRACT

Nutrient availability governs the productivity of vegetation and herbivores in ecosystems such as savannas and miombo habitats. Termite mounds are nutrient hot spots that attract grazing herbivores to their surroundings. No study has yet quantified the potential redistribution of nutrients into the surroundings away from termite mounds that might happen via grazers. We hypothesize that herbivores feeding on termite mounds are also responsible for re-distributing the nutrients into low nutrient content areas. However, we expected that the herbivores have a positive input and preferentially deposit their dung close to nutrient hot spots, thereby enforcing the hot spot and its importance in the ecosystem. We assessed soil and plant samples from 10 termite mounds for their N isotopic value and collected dung of three main herbivore species in the Issa Valley, Tanzania. Our results show that dung was more frequently deposited around mounds than further away from mounds. In addition, this dung had a similar isotopic signature as grasses around termite mounds, hence proving that herbivores, particularly grazers, are responsible for maintaining nutrient stability around these hot spots. Our study, thus, highlights the importance of herbivores in maintenance of nutrient hot spots and landscape heterogeneity in nutrient poor areas.

Keywords: Dung, herbivores, Issa valley, stable isotopes

INTRODUCTION

The grazing ecosystem is among the earth's most endangered terrestrial habitats, (Frank *et al*., 1998), often encompassing savannas that are characterised by a continuous layer of palatable and unpalatable grass species (Grant & Scholes, 2006). Nutrient availability in grasses has long been studied and found to be important for various herbivores (Treydte *et al.*, 2011). About 70%-90% of the nitrogen and phosphorus that are found in grasses are recovered in the dung and urine (Haynes & Williams, 1990). Therefore, nutrients are carried back to grasses through dung defecation and represent important sources of N and P for grasses (Haynes & Williams, 1990). Dung mineralization is higher than that of plant litter, hence, the former strongly fosters nutrient cycling (Thomas, 1992). Nutrient concentration is often high in areas of high grazer visitation (Mathews *et al.*, 2004). These areas of high grazer visitation are, for example, grazing lawns and termite mounds(Davies *et al.*, 2016). These nutrient hotspots have been shown to attract grazers. Since termite mounds are high in nutrients, one would expect that grazers favourably forage there and might, thus, also deposit more urine and dung on or next to these hotspots. Since dung and urine depositions highly affect chemical composition of soil and grasses (Moe & Wegge, 2007) as well as plant productivity (Haynes &Williams, 1990) these nutrient hotspot areas strongly support mammalian herbivore species (Grant & Scholes, 2006), especially in nutrient poor areas like savanna soils. However, the spatial and temporal nutrient cycling around these hotspot areas, from soils via plants to herbivores and back into soils, is difficult to trace and quantify (Jobbágy & Jackson, 2001).

Few studies have attempted to understand nutrient cycling in savanna systems(Buendía et al., 2018). Termite mounds are sites of high soil nutrient concentrations compared to nearby soils (Carneiro *et al.*, 2018), however, mound structure and termite behaviour together prevents the re-distribution of enriched soil from termite mounds to the surrounding landscape (Holt & Lepage, 2000). Re-distribution extent to nearby soils greatly depends on nature of the mounds, soil erosion as well as nutrient leaching rates (Holt & Lepage, 2000). However, the role that herbivores play in further nutrient redistribution away from termite mounds has never been analysed. Re-distribution rates through herbivores as agents has been reported from one area to another through dung deposited in resting or sleeping sites (Veldhuis *et al.*, 2016). However, in these studies it was difficult to provide evidence to whether the nutrient deposited in sleeping or resting places were really belong to the ungulates and the approximate distances to where they are deposited. Understanding this information is important for the long-term monitoring and maintenance of nutrient rich and productive hotspots areas. Moreover, few studies combined ungulates and nutrient re-distribution (Moe & Wegge, 2007) that might improve grazing management and nutrient availability in grazing areas (Haynes & Williams, 1990).

Stable isotopes analysis has recently been used for various ecological studies in food chains, trophic relationships, re-source allocation and various food webs (Werner et al., 2012). However, recent expansion has been given in aquatic systems (Finlay & Kendall, 2008). Little has been done in terrestrial systems using stable isotopes particularly in Eastern Africa. Weak signatures and impurities might interfere isotopic results (Werner *et al.*, 2012), hence spraying might be a good option.

We traced stable N isotopes from grasses to grazer species' faeces by labelling ten termite mounds in the Issa Valley, Tanzania. We aimed at (i) assessing the frequency of dung deposition with respect to distance away from nutrient hotspots, (ii) assessing if the dung deposited around termite mounds originated from grasses growing on these termite mounds (iii) to understand whether the nutrients are accumulated around termite mounds or rather are re-distributed away from them.

MATERIAL AND METHOD

Study Area

Our study was conducted in Issa Valley of western Tanzania (05° 23 S 30° 35 E), which consists of steep valleys and flat hill plateaus

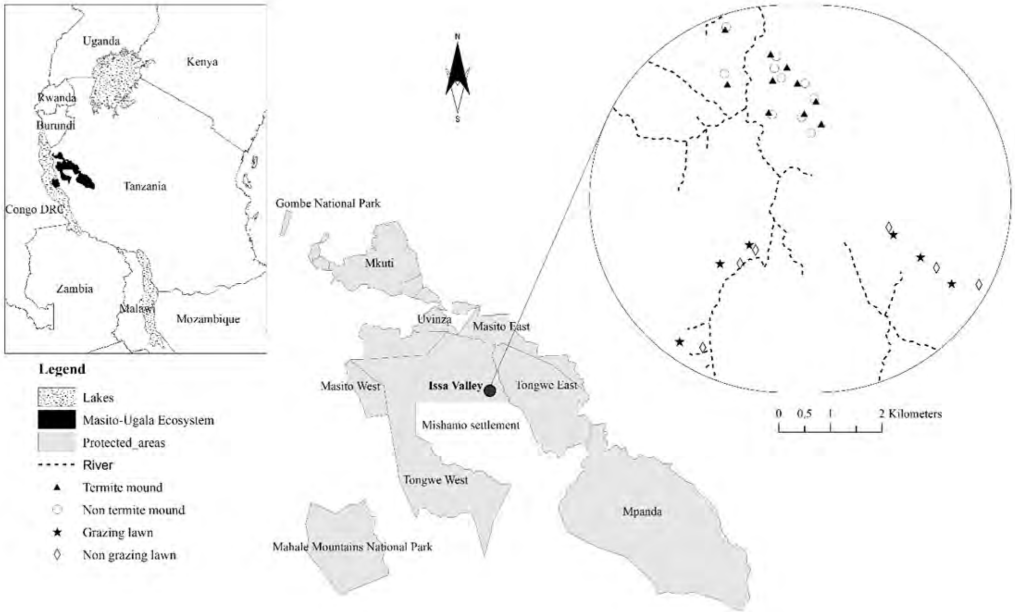

Fig 1: Map of Issa valley, western Tanzania, showing study locations at termite mounds, grazing lawns and respective control sites.

ranging from 900 - 1800 masl (Stewart, 2011). The habitat of the area is a mixture of swamps, dry grassland, wooded grassland, woodland, gallery forest, thicket forest and hill forest (Piel *et al*., 2015). Mean annual rainfall ranges from 900 to 1400 mm and there are two distinct seasons, wet (November –April) and dry (May-October) (Piel *et al*., 2015). Mean annual temperature ranges from 110C - 380C (Piel, 2014). The grassland in the study area is dominated by *Hyparrhenia hirta, Andropogon gayanus, Digitaria spp, Themeda triandra, Panicum repens* and *Oryza longistaminata* (Mayengo, in review). The woodland is dominated by miombo (*Brachystegia*) and Julbernardia (*Fabaceae*) (Piel, 2014). The main large mammalian herbivores found in the study area are Lichtenstein hartebeest (*Alcelaphus lichtensteinii*), Roan antelope (*Hippotragus equinus*) and Reedbuck (*Redunca redunca*) (Piel *et al.*, 2018). Our target species were three dominant grazing herbivores found in the study area: Hartebeest, Roan antelope and Reedbuck.

We selected ten active termite mounds covered with grass that were not close to water bodies or near big trees (to avoid potential confounding factors) as well as ten respective control sites 100 m away from the mounds (Moe *et al,* 2009). We established transects radiating away from each termite mound centre in all four cardinal directions (N, S, E, W). Along all transects, visitations of the three main grazer species Hartebeest, Roan antelope, and Reedbuck were quantified from Sept 2016 - Oct 2017 around termite mounds and their respective control sites through indirect observations using dung depositions (Treydte *et al*., 2010). The presence of different grazer species was determined by recording cumulative dung depositions (graded as 1-fresh, 2-recent, 3-old) (Curtis, 1995). After recording, dung signs were removed to avoid re-counting. Identification of the dung was done according to Stuart and Stuart (2006) and together with the assistance from experienced Tanzanian field assistants. At a distance of 2m from the centre of the mound in all cardinal directions, a quadrant of $1m^2$ was placed, within which the proportion of grasses eaten was quantified (Treydte *et al*., 2010). Extent of grass eaten before spraying urea and after spraying urea were extrapolated to cover 30 m^2 then represented in % .We foliarly sprayed 15N-Urea (Carlo *et al*., 2009) on grasses around five termite mounds within a quadrant of 2 m^2, with the mound acting as a central point and retraced the urea back in the dung collected around hotspots within a radius of 50 m^2 by being reflected by corresponding δ15N values. Proportional grass tuft usage was estimated (Grant & Scholes, 2006; Treydte *et al.*, 2010) in all sprayed termite mounds every two days after spraying urea, while collecting fresh dung pellets (4-6) from Roan antelope within a 50 m radius from the five termite mounds for three weeks consecutively. Grass samples were also collected from sprayed grass near termite mounds and at a distance of 100 m away from urea sprayed termite mound acting as a control. A total of 32 dung pellets and 32 grass samples were collected, air dried (Carlo *et al*., 2009 and Miranda *et al*., 2014), stored in paper bags and analysed at the Food Chemistry Institute, University of Hohenheim, Germany. Grass and dung samples were oven dried at 700C for 48 h (Carneiro *et al*., 2018), homogenized with milling machine (Namiesnik *et al.*, 2003) and 0.2- 0.3 mg were placed in a tin capsule (Reitsema, 2015). The delta N was determined by an Elemental analyzer intergrated via Thermo Finnigan continous flow with Isotope Mass spectrometer (Ogawa *et al.*, 2010; Reitsema, 2015). N isotope ratios were calculated as 15N where *d* represents the proportional deviation in parts per thousand (‰) from the reference standard Glutamic acid and USGS40 (Qi *et al*., 2016): *d* = 1000 (R sample/R standard) - 1), where R is the ratio of heavy to light isotopes (Markow *et al*., 2000). Each sample was replicated once to avoid errors (Peters, 2001), (Reitsema, 2015). Standard deviations for 15N were less than 0.1‰ (Rennie *et al*., 1976).

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

The presence of different animal species, recorded as cumulative dung depositions, was compared between termite mounds and control sites using one-way ANOVA. Dung data were separated into different grazer species i.e roan antelope, hartebeest and reedbuck, thereafter converted into percentage and separated into dry and wet months basing on rainfall data of Issa valley, thereafter compared using one-way ANOVA. Stable isotope data of grasses that were eaten by herbivores in selected termite mounds before spraying urea were averaged over all 5 termite mounds, thereafter compared with data that were collected after spraying urea in three different rounds using one-way ANOVA. Isotopic signatures from grass sprayed with urea close to the termite mounds were compared with control grass from non termite mounds using one-way ANOVA. Grass sprayed with urea from termite mounds were also compared with dung isotopic signatures deposited within 50 m from the sprayed grass using one-way ANOVA to evaluate isotopic signature similarity and differences (Miranda *et al*., 2014).

RESULTS AND DISCUSSION

Herbivore presence using indirect observation (dung) was about three times higher in termite mounds vs control areas ($F_{1,22} = 34.51$, $P < 0.0001$), where according to the graph rainfall seems to contribute the differences in herbivore presence (Fig.1). Seasonal differences were mainly visible in hot spot areas but not in the respective control sites, highlighting the temporal importance of nutrient hot spots. Roan antelope dung constituted 43%, Hartebeest dung 40% and Reedbuck dung 17%.

Figure 2. Rainfall amount in mm (columns) at the Issa valley in the year 2016-2017 and herbivore presence using dung depositions on termite mounds (solid line) and controls (dashed line)

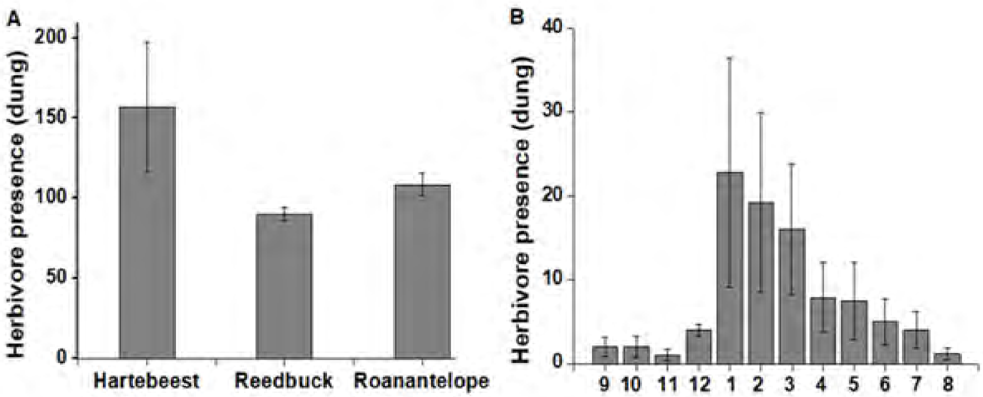

Figure 3. A. Different herbivore presence averages using dung depositions around termite mounds B. Averages of herbivore presence in different months using dung depositions between termite mounds. Percentage of grass estimates eaten by herbivores before spraying urea in selected five termite mounds differed significantly with percentage of grass eaten in three different rounds after spraying urea ($F_{1,8} = 26.60$, $P = 0.0008$). Grass percentage estimates that were eaten before spraying urea was 5% out of the whole 30 m2, while after spraying urea the estimates of grass eaten were 14%. Urea sprayed grass around termite mounds had about twice as high values in d15N compared to unsprayed grass ($F_{1,28} = 12.97$, $P = 0.0012$, Fig. 3). Further, dung deposited within a 50 m radius around urea sprayed mound grass was more closely related to urea sprayed grasses around termite mounds than control grasses away from termite mounds ($F_{1,49} = 0.233$, $P = 0.631$, Fig. 3).

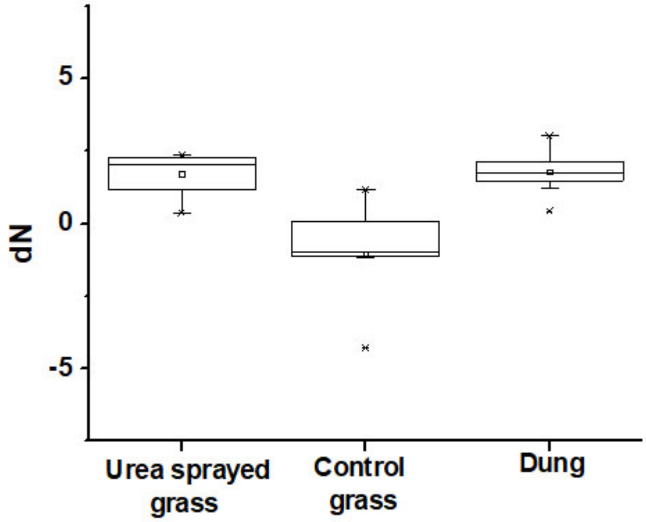

Figure 4. A. Isotopic delta N plot of urea sprayed grass (termite mound grass), unsprayed grass in controls vs dung deposited around 50 m radius from urea sprayed termite mounds.

DISCUSSION

Our study highlights that nutrient hot spots like termite mounds strongly determine the foraging preferences of grazing ungulates in the Issa Valley and our dung deposition results show that animals particularly herbivores highly use these hot spots areas than their comparative sites (Treydte *et al*., 2006; Anderson et al., 2010). Nutrient hot spots act as a key feeding resources for wild animals (Anderson *et al*., 2010), hence, determining the spatial heterogeneity in a savanna system. In our results, we also found that there were high dung deposition closer to the influence of hot spots vs far from hotspot areas. Animals, particularly grazers do not graze uniformly, but rather select patches of higher nutrition (Treydte *et al*., 2006; Davies *et al.*, 2016), like around termite mounds (White et al., 2016), and areas with low predation risks (Davies *et al*., 2016). Hence, as they graze into these higher nutrient areas ie closer to the influence of hot spots, more dung and urine are deposited around them than far away from them, (Gillet *et al*., 2010), attracting more herbivores to visit the areas (Day & Detling, 1990), because of higher nutrient content (Moe & Wegge, 2008).In our results, we also found that Roan antelope and Hartebeest showed highest dung deposition around hot spots vs reedbuck. However, for large herbivores like roan antelope and hartebeest, foraging velocity decreases and intake rate increases once they reach in areas of abundant palatable grass (Senft *et al*., 1996), which might have caused our frequent dung depositions around termite monds. Furthermore, in our study we also used novel technique of stable isotopes, rarely used in Eastern Africa in ecological studies. Isotope Ratio Mass Spectrometry (IRMS) is a specialized top novel approach used to provide useful information on chemical and biological origin of various substances (Muccio & Jackson, 2009; Reitsema, 2015). Measurement of isotope ratios can effectively be used to differentiate samples which otherwise share similar chemical signature (composition) (Muccio & Jackson, 2009). Our results showed that urea sprayed termite mound grass was a main food source for Roan, highlighting that dung deposited around termite mounds originates from grasses near termite mounds (Muccio & Jackson, 2009). This confirms that grazers enriches more nutrients by depositing dung into areas with higher nutrient contents already (Treydte, 2004) like termite mounds. However, in our study we did not use adhesive spraying urea and since our data collection was done during the rainy season, our result outcomes might have been weakened by rainfall effect (Carlo *et al*., 2009). In addition to that, physiological and metabolic processes within herbivores after eating grass might also affect our results (Zanden *et al*., 2014). However, our results still strongly suggest that herbivores contribute strongly to the existence and maintenance of nutrient hotspots in otherwise nutrient-poor savanna landscapes.

CONCLUSION

Generally we found termite mound grass have a different isotopic value than grasses further away, and dung signature was more closely related to termite mound grass signature than to non termite mound grass signature. Hence, large mammalian herbivores can enrich these important feeding grounds even more strongly, hence ensuring long persistence of these important areas in savanna ecosystems and, thereby, ensuring long-term persistence of the latter in savanna ecosystems. Furthermore, the extent to which these feeding grounds, i.e., termite mounds and grazing lawns, are important to grazers will depend on the their density and distribution patterns in a particular habitat (Holdo and McDowell, 2014).

RECOMMENDATION

Further research should be done using remote sensing for scaling up and mapping resource distribution across various seasons in the Issa valley. Additionally, this study recommends more studies on how fire and possible human disturbances in the study area impact nutrient distribution as well as different ungulate movement patterns in the area. We further suggest more isotopic studies to be done in the area to know specific grass species preferred by grazers in the study area.

ACKNOWLEDGEMENTS

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ATTITUDE AND PERCEPTION OF TOURISTS TOWARDS WILDLIFE-BASED TOURISM IN THE NORTHERN TOURIST CIRCUIT OF TANZANIA

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ABSTRACT

The tourism industry has become a fast-growing economic sector in Tanzania with high foreign earnings. In Tanzania, tourism is mostly wildlife based and highly developed in the Northern circuit. Tourism plays an important role in making land-use decisions in protected areas. The rapid growth of tourism must be pursued with care for the sake of wildlife conservation. Tourism is a clientele dependent industry, it requires a large investment in marketing and customer service to influence repeat visits. It is important to understand the attitude and perception of tourists for the development of the tourism industry. This study therefore aimed at assessing the perception of tourists on wildlife attractions, the attitude of tourists on the environmental impact of wildlife tourism and determines the demographic factors that influence their attitude and perceptions. Survey questionnaires were used to collect data from 300 tourists visiting Lake Manyara National Park and Ngorongoro Conservation Area. Data were analysed using SPSS version 20. Results show that overall; tourists have a positive attitude and perception towards wildlife tourism in Tanzania. However, there are few factors which the tourists were concerned about which pose threat to wildlife conservation such as tourist over crowding, littering, off-roading and feeding of wild animals. Furthermore, tourists were not pleased with the tourists' facilities and infrastructures. These factors must be addressed for wildlife conservation and growth of the tourism industry which has a significant contribution to the economic development of the country.

Keywords: Attitude, Development, Perception, Tourism, Wildlife

INTRODUCTION

Protected areas are important for biodiversity management and conservation, though there is no automatic link between setting aside land for conservation and achieving biodiversity management (Hutton *et al.*, 2005; Brandon *et al*., 2006). Most of the world's large national parks, conservation areas and game controlled areas are considered as institutions for conserving biodiversity (Hansen *et al*., 2002), as well as for tourism which plays an important role in making land use decisions in protected areas (Ghimire & Pimbert, 2000; Mowforth & Munt, 2005). It is sometimes perceived that protected areas cannot survive without tourism, due to facts that, the tourism industry contributes significantly to the country's capital and on conservation at large (Levine, 2002). In East Africa, tourism is often a wildlife based activity (Okello *et al*., 2008). However, Wildlife based tourism if not well managed can cause negative impacts on wildlife populations, and the environment at large (Higginbotom, 2004).

In Tanzania, tourism is estimated to contribute about 17% of the country's GDP (Tourism Report, 2016), and is among the fast growing sectors of the economy (Ruheza & Mwinuka, 2016). This rapid growth of the industry as it is based on the direct utilization of natural resources should be well managed based on sustainable conservation principles (Okello &Yerian, 2009).

Tourism in Tanzania is highly developed in the Northern Circuit. The visited protected areas include Serengeti Lake Manyara, Tarangire, Arusha, Kilimanjaro Mkomazi National Parks and Ngorongoro Conservation Area. Other important protected areas in the northern circuit include Game Reserves such as Maswa, Ikorongo, Grumet, Kijereshi, Mkungunero, and some attractive Game Controlled Areas such as Loliondo and Lake Natron. The northern circuits also habours community lands of high wildlife diversity such as Wildlife Management Areas (WMAs) of Burunge, Randulen, Makao Ikona and Enduimet. All these together attract numerous tourists every year, making the northern circuit more famous.

This study aims at examining the perception and attitude of tourists towards the wildlife based tourism in the northern circuit. Specifically, the study seeks to address tourists' perception of the wildlife attractions, evaluate tourists' attitude on the environmental impact of wildlife based tourism and determine the demographic factors that affect the attitude and perception of tourists' on wildlife based tourism.

LITERATURE REVIEW

Wildlife based tourism

Wildlife tourism refers to tourism taking place mainly in protected areas that offer the opportunity to observe and photograph wild animals in their natural habitats (UNWTO, 2014). Types of activities that are normally combined with wildlife safari include; sport fishing, cultural heritage tours and other nature-related activities (UNWTO, 2014). Conservation is an important part of wildlife based tourism (Cousins *et al*., 2009), for the past years, before the rise of mass tourism, visitors preferred to view displayed animals in zoological gardens. Initially, visitors preferred to view caged animals in zoological gardens while in present days, many tourists want to see and interact with wild species in their natural habitats and experience nature in close proximity (Ballantyne, 2009).

Attitude

Tourists' attitude is a blend of three components; an affect (a feeling), cognition (belief) and behavior (an action) (Pickens, 2005). Consumer feelings combined with consumer beliefs about a destination determine travel decisions by tourists. Tourists' attitude drives their future touristic behavior towards a destination. Behavior examined as travel behavior represents future travel plans. When international tourists carry a positive attitude about a destination, they are more likely to revisit the destination. The vice versa is true if they have a negative attitude they will be deterred from visiting and in turn discourage others to visit (Philemon, 2015).

Perception

Perception is the process by which an individual interpret and organize sensation to produce a meaningful experience (Pickering, 2010). Tourists' attitude and perception are changing as many areas of vast biodiversity are currently under increasing pressure from tourism activities (Pickering, 2010). It is crucial that visitors' perception as well as factors influencing the existing perception of protected areas are investigated and included in future management plans to achieve conservation goals (Jones *et al*., 2011). Many times, due to the dual nature of conservation, protected areas management is faced with challenges that arise from meeting both conservation requirements and visitors' expectations based on their perception of the destination (Suckall *et al*., 2009).

Tourism in Tanzania

Tanzania has incomparable numerous wildlife populations and wilderness scenery. Tanzania has set aside about 40.5% of her land for conservation, categorized as a mega- diversity nation (Brockington *et al*., 2008). Over 40% of the nation's foreign exchange earnings of Tanzania's billion dollars tourism industry are rooted in the wildlife sector which motivates Tanzania's commitment to conserving wildlife (TDPG, 2006). Currently, Tanzania receives more than 1, 284, 279 visitors and about 2 billion USD which is a tremendous multiplication as compared to 1995 when the tourism industry earned 3 million USD (MNRT, 2017).

Theoretical Perspectives

Tri-component model of attitude was used for the study. Tri-component model explains that attitude is made up of the cognitive component (beliefs), affective component (feelings), and the conative component (actions) (Pickens, 2005). The perception process follows four stages: stimulation, registration, organization, and interpretation. Perception influences attitude, it is part of the cognitive component which consists of knowledge about wildlife tourism in Tanzania, taking the form of beliefs, images and long-terms memories. The affective component comprises emotions that might be positive, negative, or mixed depending on feelings about wildlife tourism. The conative component is concerned with the likelihood behavior or actions in wildlife tourism (Harris, 2008).

MATERIAL AND METHODS

Study area

This study was carried out in two wildlife protected areas; Lake Manyara National Park (LMNP) and Ngorongoro Conservation Area (NCA) (Fig. 1). LMNP and NCA were purposively selected as among the important tourist destinations that receive most of the tourists who visit the northern circuit and to avoid respondent repetition as most tourists who visit SENAPA also visit NCA. Approximately 70% of all visits in the country are concentrated in the Northern circuit and are wildlife based (MNRT, 2014). For example, in 2016, Ngorongoro Conservation Area received 37.8% of tourists; Serengeti National Park, 24.9%, Lake Manyara National Park, 11.2%, Tarangire National Park 10.1%, Kilimanjaro National Park 4.9% and Arusha National Park, 1.4% (DTIS, 2017). Field data sampling.

Research Methodology

Random sampling was employed as a sampling technique; this is due to the fact that tourists arrive at the national park and conservation area at different times and varying in number. Random sampling is a form of probability sampling by which each individual of the population has an equal chance of being selected.

Data collection

Data was collected through 381 questionnaires which were distributed to tourists at the main gates of Lake Manyara National Park and Ngorongoro Conservation Area. Out of the total distributed questionnaires, 300 questionnaires were returned from both areas. The study employed structured questionnaires with close and open ended questions to collect information from the respondents. Data collection was done for 8 weeks between November and December 2017. On each day data collection commenced from 7.00 am to 10.00 am and another session

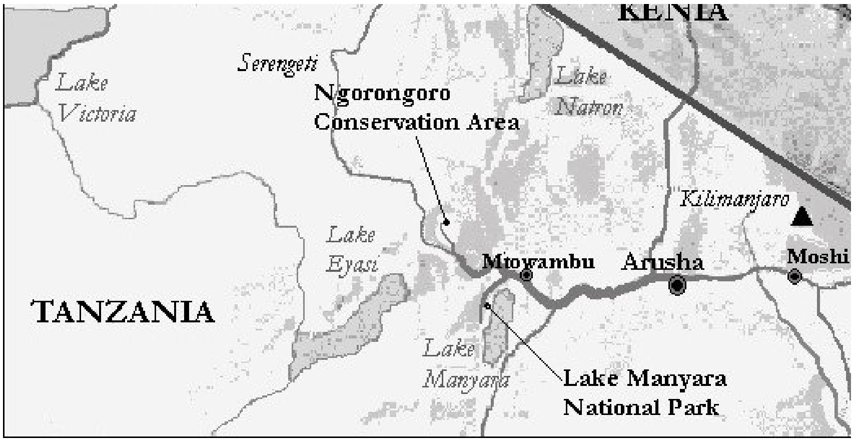

Fig. 1. Map of the study area

from 3.00 pm to 5.00 pm. The selected time slots indicated the peak where most tourists' vehicles arrived at the gate of the respective parks. In order to reach the tourists and get their attention to fill the questionnaires, driver guides were approached to ask their visitors to be respondents for the survey. The questionnaires were in English and the tourists were asked to individually fill them. The tour guides were asked for assistance to interpret the questions from the questionnaires for the tourists who were non-English speakers.

Data Analysis

Statistical Package for Social Sciences (SPSS) version 20 was used for data analysis. Data were analyzed using both descriptive statistics (Frequencies, Mean, and Standard Deviations) and Inferential Statistics (t-Tests). Ratings of attractions, perception and attitude toward wildlife tourism were analyzed descriptively by frequencies and mean scores. All statistical analysis was conducted at the alpha=0.05 significance level.

RESULTS AND DISCUSSION

Demographic characteristics of the Respondent

The respondents were tourists who came to visit the protected areas in Tanzania. It was

Table 1. Respondents age profile

Sex	Frequency	Percent(%)
Male	150	50.0
Female	150	50.0
Total	**300**	**100.0**

Table 2. Age categories

Age range (Yrs)	Frequency	Percent(%)
10-19	10	3.3
20-29	80	26.7
30-39	96	32.0
40-49	49	16.3
50-59	33	11.0
>60	32	10.7
Total	**300**	**100.0**

Table 3. Level of education

Level	Frequency	Percent(%)
Non formal	3	1
Diploma	34	11.3
Bachelor	148	49.3
Masters	92	30.7
PhD	22	7.3
Juris Doctors	1	0.3
Total	**300**	**100.0**

Table 4. Occupation diversity

Occupation	Frequency	Percent(%)
Private sector	3161	53.7
Civil servant	53	17.7
Self employed	43	14.3
Retired	18	6.0
Student	25	8.3
Total	**300**	**100.0**

Sex of respondents

Sex ratio was equal for both male and female (Table 1). This is in line with the Tanzania tourism sector survey report of 2017 that there was no significant difference between the number of male and females tourists arriving in Tanzania (WTTC, 2017).

Age of respondents

The study found that 75% (n=225) of tourists visiting LMNP and NCA range between 20-50 years (Table 1), which was regarded as adulthood age class. The findings were supported by another study that, majority of the tourists who visited the national parks in Tanzania came during their adulthood, it is at this age range when they are energetic, seek adventures and new experience (Sarma, 2004).

Level of education

About 49.3% of respondents have first degree, 11.3% have diploma level, and 7.3% have attained doctorate degree (Ph.D.), while only 1.0% had no formal education. This indicates that education had played a significant role in motivating tourists to participate in wildlife tourism.

Occupation

In total, the employed group of tourists account for 71.4%, this could be related to the ability of the individual to save money form their salaries. Results from this study are supported by Chowdhury (2017) who argued that most of the tourists belong to the employed group and very few tourists belong to the retired group which is also a fact in the findings of this research.

Origin of Respondents

As indicated in Fig. 2, most of the tourists came from the United States of America (23%), German (14%), France (13.3%), and the United Kingdom (7.3%). Most of the tourists came from the US and Europe, possibly due to high marketing and promotion done by tour companies in these countries where they have established networks. Another explanation for this could be the timing of the study survey which collided with the tourists' holiday season from these countries. The number of American tourists was higher as compared to other nationalities followed by Germans, French and Swedish. The higher number of visitors from America was probably due to the reason that in most cases, Americans seek new experiences and are also interested to learn new cultures (Mohammad and Som, 2010; Pantouvakisa & Patsiourasas, 2016).

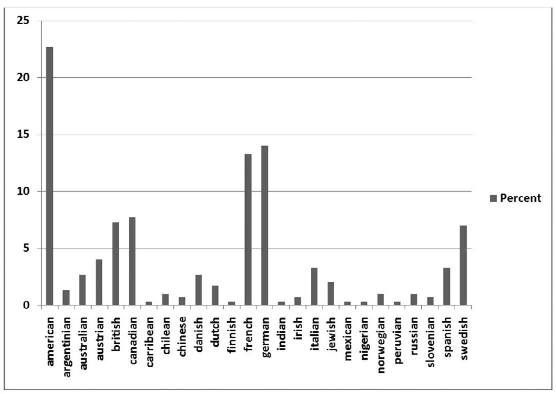

Fig. 2. A graph showing nationality of tourists

Source of information

When the respondents were asked how they heard about the destination, 40% responded that they heard from family, 5.7% from friends, 29.7% of the tourists got information from websites and the lowest 1% was from exhibitions (Table 2). This indicates that, once tourist has a more positive attitude of the destination, could positively share the same to family members and friends. Findings are supported by East et al., (2006), that a good word of mouth is more credible and plays an essential role in destination choice The lowest percentage of source of information from exhibitions gives an indication that as a country more effort is needed in promoting our tourism products through exhibitions all over the world, and that, probably exhibitions are not enough and or reliable means of promotion and a marketing strategy or majority are not aware of such events. Efforts to include other marketing strategies such as social media need to be promoted.

Table 5. Sources of information

Source	Freq	Percent(%)
Family	120	40.0
Website	89	29.7
Social media	17	5.7
Television	12	4.0
Part of program	7	2.3
Travel agency	28	9.3
Friends	17	5.7
Social media	7	2.3
Exhibition	3	1.0
Total	**300**	**100.0**

Number of visits

Results in Table 3 indicate that majority of tourists are first time visitors (82.3%) with very few repeat visitors. Reasons for low repeat visits were attributed to perhaps negative experience on the previous visit. Negative tourist experience at the destination area can influence tourist attitude and perception which could affect their repeat visitations (Yu-Ting and Dean, 2001; White, 2005). Another reason was related to economic constraints that, it is costly to visit the national parks in Tanzania. It has been reported that in most cases one of the reasons for failure to revisit the destination is the higher costs related to tourism packages (George & George, 2012). Furthermore a desire for new experience; this poses a challenge to tourism destination managers to diversify tourist attractions so as to increase the number of repeat visits (Oppermann, 2000; Petrick, Morais & Norman, 2001). Improved and good tourists facilities and services could encourage visitors to plan for future revisiting of destinations (Warnken, 2015), it is, therefore, important to ensure that the visitors have a positive experience on each visit so as to increase the number of repeat visitors who will be loyal to the destinations.

Table 6. Number of visits

visits	Frequency	Percent(%)
1	247	82.3
2	40	13.3
3	6	2
4	4	1.3
5 or more	3	1.0
Total	**300**	**100.0**

Length of stay

A one-sample t-test was performed to make a comparison between the average length of stay according to the visitors' exit survey 2016, whereby the dependent score was the length of stay while the independent score were the demographic factors. Results indicated a significant difference between the length of stay of tourists reported by the TTSS (2017) and from this study (p-value<0.05). This study found an average of 11±2.758 days while the TTSS (2017) found an average of 9 days. The increase of the length of stay of tourists might be due to the kind of holiday packages with more days offered by the tour companies, plus efforts by the government to increase marketing and promotion of the destination. These findings agree with other studies which found that despite some negative experience tourists were generally satisfied with their visit in Tanzania (Shemma, 2014; Philemon, 2015).

Table 7. One sample T-test on length of stay IN Tanzania

	Test Value =3					
	t	df	sig (2-tailed)	Mean difference	95% Confidence interval difference	
					Lower	Upper
Stay days	14.002	299	.000	2.23	1.9166	2.5434

Tourists' Perception on the Wildlife Attractions in the Northern Circuit

Sites visited

The study found that most of the tourists 61% (N=300) who arrived at the Northern circuit visited the national parks, while 19.7% visited cultural sites and national parks and the lowest 0.3 visited schools (Table 5). Reasons for more visitors to the national parks were related to reasons that, most of the parks are well advertised with more emphasis on wildlife attractions compared to other tourism products, parks can be easily accessed through tour operators' services and have better tourist facilities as compared to other tourism sites. Preferred services that attracted more tourists into the park were good accommodation facilities (i.e. lodges and camps) within or near national parks, scenic beauty that include natural environment and diverse wildlife species in big groups, other attractions such as cultural sites and historical sites were regarded as less attractive in the northern circuits. The findings are supported by the study done by Kaltenborn et al., (2011).

Tourists' Attitude on Environmental Impact of Wildlife based Tourism

A high mean of 4.94 and low (Std 1.120) (Table 6) was obtained from the attitude towards overcrowding which implies that tourists have a negative attitude toward crowding and believed that a high population of tourists have an impact on the environment within the protected areas. This affect tourists' experience, it reduces visibility towards nature, it also causes discomfort and decreases opportunities for a peaceful and higher level of enjoyment (Smith & Newsome, 2002; Yang & Zhuang, 2006; Moyle & Croy, 2007). Tourists also reported a negative attitude towards pollution caused by vehicles which are believed to cause both air pollution and noise pollution. Other factors were rated roughly equal; few believed that tourists have a behavior of feeding wild animals as well as throwing litter within the protected areas which area violation of park rules(mean of 3.73 and Std of 1.24). However, it was found that in the Lake Manyara National Park most of the litter especially near the lake was from the village side surrounding the national park as reported by tourists during a conversation. The lowest mean of 3.56 and high (Std 1.277) was obtained from the statement that tourists tend to off-road. On average tourists are pleased with the current environmental conditions of the national parks, they do not observe much environmental impact from their level of activity, but they are more troubled on the possible future environmental changes (Kaltenborn *et al*., 2011).

Table 8. Site visited by tourists

Site visited	Frequency	Percent (%)
Cultural sites	4	1.3
National parks	183	61.0
Schooös and national parks	1	0.3
Beach_zanzibar and national parks	12	4.0
Cultural sites and national parks	59	19.7
Cultural sites, historical sites and national parks	25	8.3
Archaeological, historical and national parks	16	5.3
Total	300	100

Table 9. Causes of environmental impact

Causes	N	Frequency	Percent (%)
Crowding has an environmental impact	300	4.93	1.120
Tourists have a behavior of feeding Wild animals	300	3.78	1.368
Tourists' vehicle cause pollution	300	4.29	1.066
Tourists do litter the protected areas	300	3.73	1.237
Tourists tend to off-road	300	3.56	1.277

The attitude was more positive on the attributes of the natural environment as shown in table 8. A high mean of 5.07 and low (Std 1.042) was obtained from the statement relating to the uniqueness of the protected areas. The mean values indicated that the tourists considered LMNP and NCA as unique places in the world and as one of the best places to experience wildlife in a natural environment. On the other side, 77% of respondents were in favor of important tourists' facilities such as information centres, signage, rest houses, toilets, and picnic sites be increased. Tourists (65%) complained about poor services and safety gaps especially on campsite areas and toilets.

Table 9: Causes of environmental impact

Causes	N	Frequency	Percent (%)
LMNP/NCA is unique diff from any other place in the world	300	5.07	1.042
There are too many tourists in LMNP/NCA	300	3.82	1.156
Tourists' facilities (information centres, rest houses, toilets, signage and picnic sites) should be increased in LMNP/NCA	300	4.00	1.073
Good wildlife sites are often overcrowded with tourists	300	4.11	0.971
There are too many vehicles in LMNP/NCA	300	3.66	0.997

CONCLUSION

Tourists' expectations were met to a certain level despite some inconveniences. It has been found that first time visitors rely on the word of mouth as a source of information for destination. Tourists do agree that the vehicles used caused air and noise pollution within the national parks; some did admit that there was some behavior misconduct by tourists within the national parks such as littering, feeding wild animals and going off-road. Overcrowding, again especially during the high season, caused uncomfortable experience to the tourists. Some aspects of the trip reduced the quality of tourists experience and had a negative impact on the environment. Despite the negativity, tourists had a stronger positive attitude and perception towards wildlife tourism in Tanzania as indicated by their plan to stay for many days during the visit. Therefore, tourists were generally pleased with their visit in Tanzania.

RECOMMENDATIONS

i) The Ministry of Natural resources and Tourism together with the Tanzania Tourist Board (TTB) need to improve marketing strategies in order to reach a wider audience. The use of social media can reach more potential tourists in a short time.

ii) Tanzania National Park Authority (TANAPA) and Ngorongoro Conservation Area Authority need to make sure that they provide the best quality services to visitors so as to get a good word of mouth since tourists trust the recommendation they receive from their families and friends.

iii) Protected areas need to enforce visitor management techniques to address overcrowding; setting a limit of the number of vehicles that can enter the national parks and conservation area in a day during high season, the limitation can even go further to set the maximum number of tourists in a vehicle, this can be achieved by knowing the carrying capacity of the destination.

iv) There is a need for the government to design special facilities and packages that will meet specific wants of a potential market segment that has been neglected that is the retired individuals. Furthermore, there is a need to diversify tourism products to capture large tourists market including repeat visits because from the results, the majority of tourists coming to Tanzania come for wildlife tourism.

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CHARACTERIZING AFRICAN ELEPHANT MOVEMENTS OUTSIDE OF PROTECTED AREAS IN THE WESTERN SERENGETI, TANZANIA

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ABSTRACT

The severe and widespread nature of negative human-elephant interactions in the western Serengeti has adverse impacts on people's livelihoods, which translates to reduced support for conservation efforts, the retaliatory killing of wildlife, and encourages potentially harmful illegal resource extraction within protected areas. In order to further develop our understanding of human-elephant interactions and elephant movement behavior in the western Serengeti, 30 elephants (15 bulls, 15 cows) were collared within the Ikorongo-Grumeti Game Reserve Complex and Ikona WMA between February and September of 2018. We summarized movement statistics and characterized activity outside protected areas by sex, time of day, time of year, and speed. We assessed the movements of four bulls between Serengeti National Park and Lake Victoria and explored implications for habitat connectivity. Collared elephants predominantly spent time inside protected areas, with lower proportions of time spent within villages and semi-protected areas like grazing and Game Controlled Areas. While bulls were found to have significantly larger home range areas on average than cows, the proportion of time spent outside protected areas was not found to differ significantly between bulls and cows. The timing and characteristics of movement outside the protected area varied between individuals; while many individuals spent increased proportions of time outside the reserve between 7pm and 3am, others spent high proportions of time outside the reserve regardless the time of day. Similarly, the annual timing of activity outside the protected area varies between individuals, but overall, peaked between June and August and again between October and November. We found that there is a need to consider how land use planning can be utilized in this area to maintain movement corridors between protected areas and important unprotected habitat features while simultaneously reducing negative interactions between elephants and people.

Keywords: Elephant, Movement, people's livelihood, Western Serengeti

INTRODUCTION

The severe and wide spread nature of negative human-elephant interactions in the western Serengeti has adverse impacts on people's livelihoods, which translates to reduced support for conservation efforts, the retaliatory killing of wildlife, and encourages potentially harmful illegal resource extraction within protected areas. Elephant population in the western Serengeti has been increasing at an annual average rate of 7.5% since 2002; more than 1500 animals utilize the Ikorongo and Grumeti Game Reserve complex during the dry season (Goodman & Mbise, 2018). Paired with extensive conversion of the adjacent unprotected landscape for agriculture and a rapidly growing human population, the frequency of elephant-induced damage to crops has increased in recent years (Denninger Snyder et al., 2019).

Tracking individual animals is a popular approach to study wildlife and can provide a wealth of insight into the context in which animals interact with and utilize the environmental landscape (Wittemyeret al., 2019). In particular, fitting African elephants (*Loxodonta africana*) with GPS collars has provided invaluable insights regarding social behaviour, resource utilization, response to land cover change and risk, and for use in many conservation applications, such as corridor development (Bastille-Rousseau *et al*., 2020; Bastille-Rousseau *et al*., 2018; Cook *et al*., 2015; Graham *et al*., 2009; Mmbagaet al., 2017; von Gerhardt *et al*., 2014; Taylor *et al*., 2019; Wittemyer *et al*., 2007).

In 2018, our project carried out an elephant collaring program in th e western corridor of the Serengeti ecosystem, with the ultimate aim of facilitating management interventions and informing conservation planning efforts via an improved understanding of human-elephant interactions, elephant movement, and crop raiding behavior. Here, we present an interim analysis characterizing elephant utilization across a matrix of protected, semi-protected, and unprotected areas in the western Serengeti, and describe long-range and trans boundary movements observed during the study period.

MATERIALS AND METHODS

This study was conducted in the western corridor of the Serengeti ecosystem (Fig 1). During two primary collaring phases in February and September of 2018, we fit 30 individual elephants (15 bulls, 15 cows) with GPS collars. Animals were collared within the Ikorongo and Grumeti Game Reserves and Ikona WMA according to dry season density as recorded via aerial survey. All collars were Savannah Tracking units set to record fixes at 30-minute intervals. In this analysis, we only included animals for which we had at least one year of data (n=29).

Home range metrics were derived using the 95% utilization distribution. Refuge habitat and agricultural areas outside of protected areas were derived from a 2018 ecosystem-wide land cover classification (Anna Estes, 2019, unpublished data). The Mann-Whitney test was used to evaluate differences between bulls and cows with respect to home range size and proportion of time spent by protected area status and land cover class. Simple and paired ANOVA were used to evaluate the influence of time of day and protected area status on log-transformed movement speeds.

We further characterized elephant movements by producing activity budgets for each animal and examining variations in the timing of behavioural state by protected area status. Hidden Markov Models were constructed using movement attributes (speed and tortuosity) and environmental covariates and then applied to predict one of three behavioural states for each fix. The three behavioural states were encamped (low speed

Fig. 1. Map of the study area

and high tortuosity), foraging (increasing speed and decreasing tortuosity), and goal-oriented (high speed and directed movement). Long-distance and transboundary movements were qualitatively assessed using GIS.

RESULTS

Characterizing movement

Home range sizes ranged from 265 km^2 to 6521 km^2 and differed significantly ($p < 0.01$) between bulls ($\bar{x} = 3486$ km^2) and cows ($\bar{x} = 1642$ km^2). The proportion of time spent outside protected areas was highly variable between individuals; on average animals spent 29% of their time outside of protected areas, with 17% of time spent in unprotected village land and 12% of time within limited use areas. There was no observed difference between night and day in proportion of time spent outside protected areas ($p = 0.17$), and bulls and cows did not differ with respect to proportion of time spent in settlements ($p = 0.29$) or limited use areas ($p = 0.74$). While outside of protected areas, on average 70% of time was spent in refuge areas, and 30% of time in agricultural areas, with significantly more time spent in agricultural areas during the night ($p < 0.001$). No statistical differences were observed between bulls and cows in the proportion of time spentin agricultural areas ($p = 0.62$).

Time of day, protected area designation and land use were observed to influence movement speeds (Fig 2). Within protected areas, day time speeds were significantly higher than night time speeds ($p < 0.001$). Outside of protected areas, daytime and night time speeds did not differ ($p = 0.86$), and night time speeds were significantly higher outside of protected areas than within ($p < 0.05$). Night time movement speeds outside of protected areas were significantly higher in agriculture than refuge habitat ($p< 0.1$). The comparison of activity budgets by protected area status further supports these results, illustrating that over night foraging was somewhat higher on unprotected land and that goal-oriented movements noticeably shift from primarily occurring within daytime hours inside of protected areas to predominantly overnight outside of protected areas (Fig 3).

Long distance movements

During the course of the study several collared animals undertook notable movements north to the Mara swamp, east to the Maasai

Mara, west to Lake Victoria, and south to Maswa GR. These movements were sexually biased, all were undertaken by bulls. The Mara swamp is located approximately 50 km north of Makundusi grazing area and is isolated from the Ikorongo-Grumeti Game Reserve complex by a densely settled agricultural matrix. Over six days in December 2018, a prime age bull travelled 197 km through this matrix in the company of a small cow-calf group. Visual evaluation of the bull's movements illustrated utilization of small refuge areas for daytime resting and long directional movements overnight. In total, the bull spent less than 12 hours along the edge of the Mara swamp.

Three collared bulls were observed to traverse international boundaries and utilize the Maasai Mara in Kenya. While two of these animals utilized the Maasai Mara intermittently and infrequently, one bull utilized the Maasai

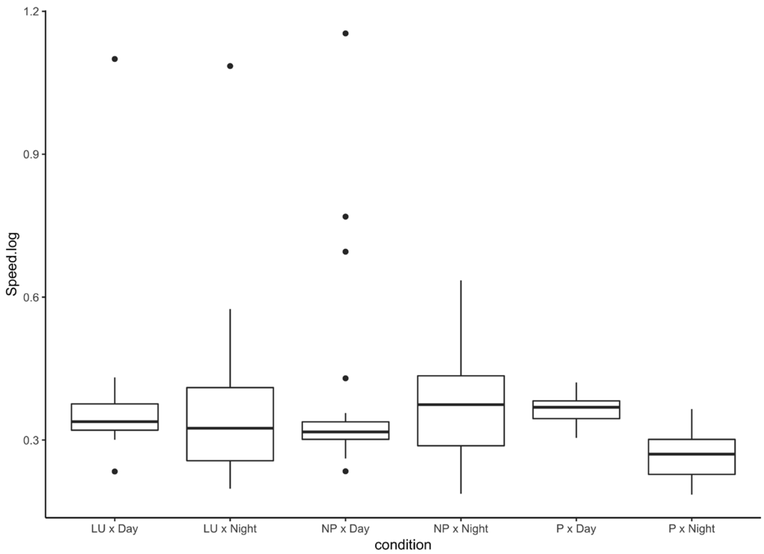

Fig. 2. Movement speeds by protected area designation (LU = limited use, NP = not protected, P = protected) and time of day

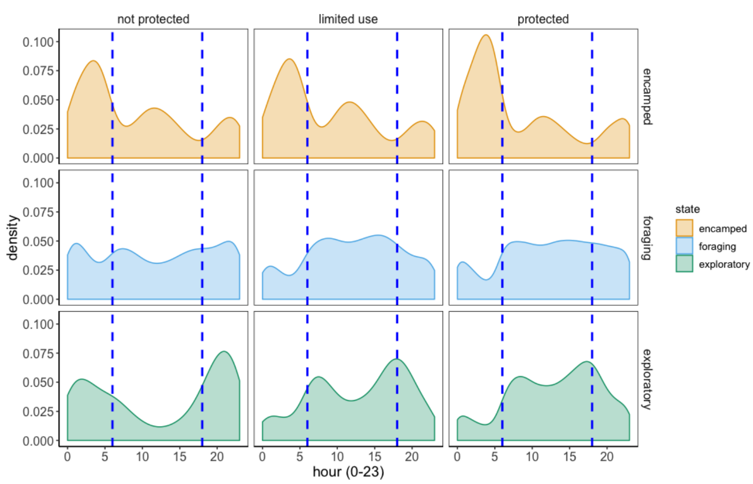

Fig. 3. Temporal activity budgets showing the activity density of three behavioral states (encamped, foraging, and exploratory or directional movements) by protected area designation and hour of day

Mara National Reserve for multiple months between May and July in both 2018 and 2019.

Six bulls were observed to utilize the densely settled area east of Speke Gulf, the unprotected stretch of land between Serengeti National Park and Lake Victoria. Movements were concentrated along the Grumeti River to the north and the Mbalageti River to the south, with intermittent movements into settlements. In order to access the lake edge, collared animals often moved through settlements overnight.

Two bulls were observed to make repeated north-south movements between Grumeti Game Reserve and southern Maswa along the edge of Serengeti National Park and Maswa Game Reserve. One of these bulls was observed to almost exclusively utilize edge habitat along the western edge of the ecosystem, making regular overnight forays into settlements and seeking refuge in the protected area during the day (Fig 4).

DISCUSSION

The Mara Region is the most densely settled region of those adjacent to the Serengeti ecosystem within Tanzania. Although much of this area has been converted for agriculture, elephants still regularly utilize refuge habitat outside of protected areas. Collared animals were observed to utilize formally designated grazing areas, informal open areas, wooded hills unsuitable for agriculture, and small wooded patches preserved within the agricultural matrix. Further investigation is required to better understand the functional and structural value of these areas (Wittemyer *et al.*, 2019),

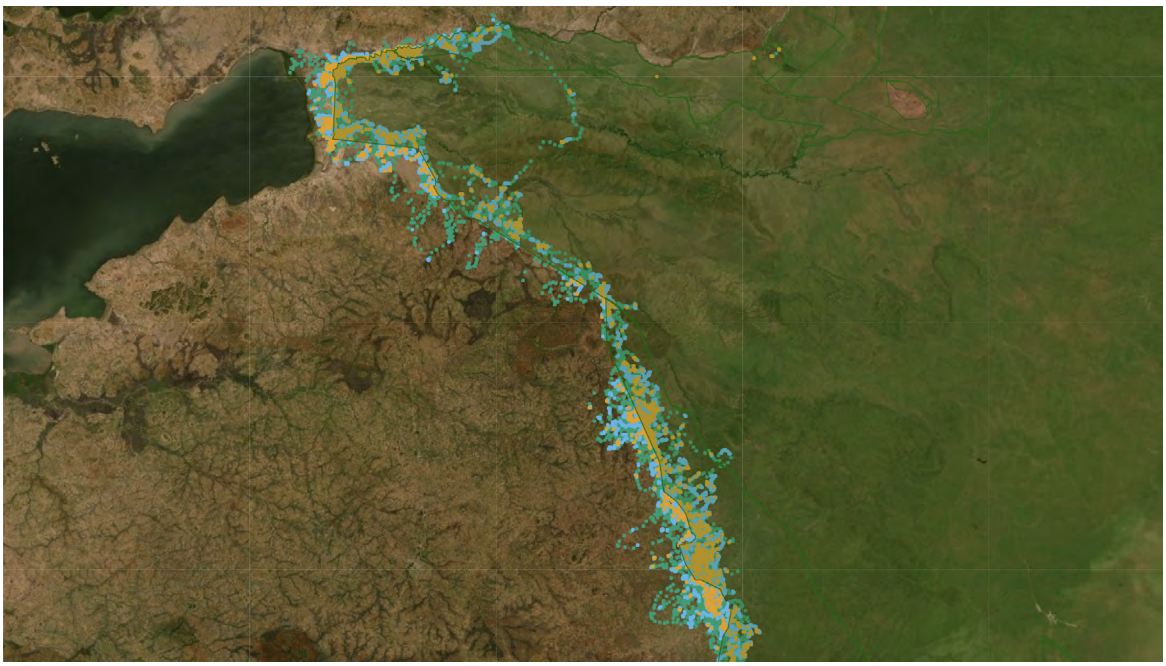

Fig. 4. Movements of one study bull along the western edge of the Serengeti ecosystem. Points are individual fixes with collars coordinating with behavioral states (orange = encamped, blue = foraging, green = directional).

and particularly to what extent the utilization of unprotected refuge habitat is associated with crop raiding behavior.

Throughout their range, the social composition of crop-raiding elephants is variable. Near Udzungwa Mountains National Park in south-central Tanzania, crop raiding has been observed to be a behavior exclusive to bulls (Smit *et al*., 2019), and other studies have also reported strong biases towards bulls (Chiyo *et al.*, 2011; Graham et al., 2010). In the western Serengeti cow-calf groups are commonly reported to enter settlements and raid and trample crops. The movement data supports these anecdotes; while we observed high individual variability, there was no obvious distinction between bulls and cow-calf groups in their utilization of habitat outside of protected areas with respect to proportion of time spent by protected area status, land cover type, or time of day. However, given the sexual bias in long distance movements and through what could be considered areas of high risk, there is a need to examine this topic more deeply with respect to differences in functional value, activity patterns, and risk avoidance strategies.

As reported elsewhere, we observed that elephants modified their behavior relative to risk movement speed is commonly used as an indicator of behavior and response to risk (Douglas-Hamilton *et al*., 2005; Jachowskiet al., 2013; Wittemyeret al., 2017). Within protected areas, movement speeds were greater during the day than at night, which is reflective of typical activity patterns where elephants rest and move less at night and forage and are more active during the day (Wittemyer *et al*., 2017). Conversely, we observed increased night time activity outside of protected areas which may be indicative of behavioral shifts in order to avoid risky encounters with people (Wittemyer *et al*., 2017).

The long-range movements observed indicate that the continued connectivity of the Greater Serengeti-Mara Ecosystem is critical to sustain connectivity between populations and across international borders. Elephants currently access isolated resources such as Lake Victoria and the Mara swamp by traversing across densely settled areas; options to maintain and improve access to important, isolated resources while reducing conflict between people and wildlife must be explored.

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HOUSEHOLD ECONOMIC CONDITIONS AND BUSHMEAT CONSUMPTION: A LONGITUDINAL ANALYSIS OF COMMUNITIES IN WESTERN SERENGETI, TANZANIA

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ABSTRACT

Bush meat is among the most widely consumed protein by people living around Tanzania's Serengeti ecosystem, and poses a significant threat to wild ungulate populations. The market for bush meat is driven by factors which change over time. Understanding how changes in bush meat consumption are affected by the dynamics of household economies can help identify conservation strategies that can successfully reduce bush meat consumption without compromising food security or income generation for local communities. Previous research in this area identified the potential for alternative protein sources, in particular beef, as a substitute for bush meat consumption. We utilized a longitudinal panel data set of self-reported protein consumption and livestock health of 132 households from eight villages in Western Serengeti to assess changes in bush meat consumption from 2007-2014 in relation to changes household livestock ownership, and the introduction of micro-credit groups aimed at improving conservation-friendly livelihoods for bush meat hunters. We determined that as household cattle ownership (a proxy of wealth) increases, beef consumption does not increase, but bush meat consumption does. This suggests that while improving beef production at a landscape level could, in theory, provide a substitute for bush meat, in practice, strategies aimed at reducing demand for bush meat by increasing household domestic livestock holdings are unlikely to have the desired effect. We also find that the initiation of micro-credit groups coincided with a reduction in bush meat consumption at the village level, perhaps through reducing the local supply of bush meat.

Keywords: bush meat consumption; economics of bush meat; development and conservation; village savings and loans association.

INTRODUCTION

Bush meat, or wild meat, is an important food source for many rural communities throughout Africa (Milner-Gulland *et al*., 2003, Cowlishaw *et al*., 2005, Brashares *et al.*, 2011, Lindsey *et al.*, 2013, Nielsen *et al*., 2018). As human populations increase and wildlife is increasingly confined to protected areas, the impact of bush meat hunting is an increasing concern for conservation (Robinson & Bennett 2002, Brashares *et al*., 2004, Tilman *et al*., 2017). Offtake of wildlife for bush meat consumption threatens even vast ungulate populations in large protected ecosystems, like the Greater Serengeti (Kaltenborn *et al*., 2005, Hilborn *et al*., 2006, Rentsch & Packer 2014, Damania & Scandizzo 2017, Veldhuis *et al*., 2019).

At the same time, human populations living near wildlife rich areas often rely on livestock and agricultural production as their primary livelihood strategy (Harris *et al*., 2009, Riggio *et al.*, 2019). Crop and livestock production draw on resources (like land and water) that directly affect the health of the ecosystem upon which wildlife populations rely. Poor households in these communities often simultaneously engage in agricultural and bush meat harvesting activities to ensure their food security (Loibooki *et al.*, 2002, Knapp, 2007, Mfunda & Røskaft 2011, Nyaki *et al*., 2014).Understanding how agricultural household decisions interact with bush meat consumption which affects the health of the Serengeti ecosystem, is important for developing long-term sustainable development and livelihood strategies. This study uses longitudinal data from the Serengeti region in Tanzania to investigate this relationship.

The regions surrounding western Serengeti have among the highest human population densities in Tanzania, and are growing at nearly three percent per annum, with growth rates even higher adjacent to the protected areas (Estes *et al*., 2012). This growth drives demand for bush meat, which was estimated at nearly two and a half meals per household per week (Rentsch & Packer 2014). With increases in the number of consumers, even a small change in average household consumption can have a magnified impact on wildlife populations (Lindsey *et al*., 2013, Rentsch & Packer 2014, Damania & Scandizzo, 2017).

In addition to extensive law enforcement efforts to combat illegal wildlife hunting, which consumes the greatest proportion of financial and human resources for protected areas in the Serengeti ecosystem (Arcese *et al*., 1995, Hilborn et al., 2006, Dobson & Lynes 2008), several interventions have been proposed to reduce demand for bushmeat among local communities. These include improving access to alternative protein sources, and income-generating opportunities targeting bush meat hunters (Loibooki *et al.*, 2002, Kaltenborn *et al*., 2005, Nyahongo *et al*., 2009, Bitanyi *et al*., 2012, Rentsch & Damon, 2013, Fischer *et al*., 2014, Moro *et al*., 2015). In this study, we empirically investigate the effectiveness of these strategies on bush meat consumption.

Specifically, our study examines the relationship between bush meat consumption and livestock ownership, since beef is an important protein alternative; bush meat consumption and rainfall (a key driver of agricultural productively); and the effectiveness of a micro-credit program meant to provide livelihood alternatives to communities with high proportion of bush meat hunters. In the absence of direct measures of bush meat off take, longitudinal data on bush meat consumption provide information about demand for bush meat (Knapp *et al*., 2010, Rentsch & Damon 2013). We utilized a panel data set of self-reported protein consumption in eight villages in western Serengeti from 2007 to 2014.

MATERIALS AND METHODS

The Greater Serengeti ecosystem encompasses roughly 12,000 square miles, 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). The Serengeti ecosystem includes Serengeti National Park at its core, surrounded by game reserves (Grumeti, Ikorongo, Maswa and Kijereshi), Loliondo Game Controlled Area, the Ngorongoro Conservation Area, and two Wildlife Management Areas, which function as buffer zones between protected areas and village lands (Fig.1).

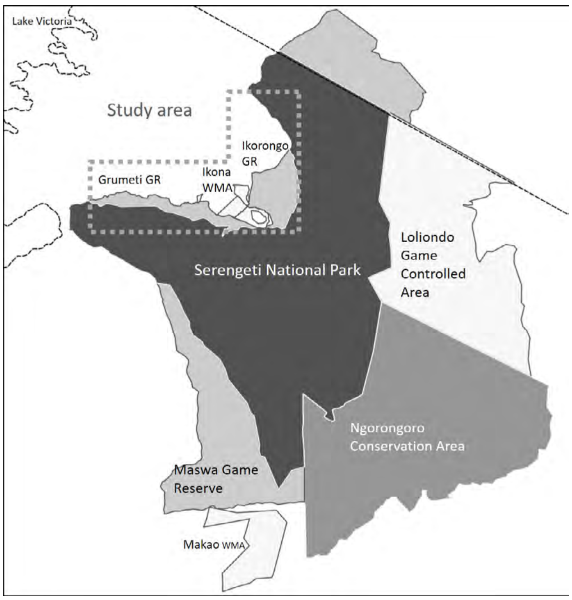

Fig. 1. Study area

Bush meat hunting in Western Serengeti is driven by cultural identity, preference for wild meat, and the need to supplement household income (Loibooki *et al*., 2002, Kaltenborn et al., 2005, Galvin *et al*., 2008, Ndibalema &Songorwa 2008, Knapp, 2012, Walelign *et al*., 2019). The majority of meat hunted is not consumed directly by the hunter or his family, but sold to neighbors within the hunter's home village, or to traders who transport the meat to external markets (Knapp *et al.*, 2010, Knapp, 2012, Nyaki et al., 2014). This, together with the use of more efficient (and largely indiscriminate) hunting tools such as wire snares, and even motorcycles, suggests that it is most helpful to view bush meat hunting as a business rather than as a means of subsistence. While we know that bush meat is marketed, we know less about how bush meat consumption interacts with agricultural outcomes. In this paper, we examine how bush meat consumption is affected by livestock ownership and offer preliminary evidence about the ways that livelihood alternatives might influence the local bush meat market.

In western Serengeti, bush meat remains one of the most widely-consumed protein sources among the predominately agro-pastoralist communities (Loibooki *et al.*, 2002, Nyahongo *et al.*, 2009, Rentsch & Packer 2014). While hunters typically originate from the surrounding communities, most hunting takes place inside of the protected areas. Hunters travel many kilometers inside the protected areas to avoid detection and set their snares (Campbell &Hofer, 1995, Hofer & East 2000, Kaltenborn *et al.*, 2005, Knapp, 2007, Metzger *et al*., 2007).

Key Factors that Affect Bush meat Consumption

Relationship between livestock ownership and bush meat consumption.

Both domestic livestock and bush meat play important roles in fulfilling household demand for protein in Western Serengeti. Consumption of protein in Western Serengeti is highly elastic with respect to changes in its own price as well as prices of alternative protein (Rentsch & Damon, 2013). Bush meat consumption was also found to increase significantly with increases in expenditure (a proxy for wealth). These findings lead to two plausible hypotheses with respect to the relationship between livestock production and bush meat consumption. First, we have evidence that both fish and beef are strong substitutes for bush meat. This would mean that higher productivity of beef and fish – and thus lower prices - may result in a decrease in consumption of bush meat (Rentsch & Damon, 2013). Second, livestock in the agro-pastoral communities surveyed also serves as a store of wealth. Given the strong positive relationship between bush meat consumption and wealth it is possible that increasing wealth may increase consumption of bush meat. Household livestock numbers therefore have two potential effects on bush meat consumption, working in opposite directions. We empirically investigate this effect to see which one dominates, using observations from a continuation of the same data set used in Rentsch & Damon (2013).

Provision of credit and bush meat consumption. Community Conservation Banks (COCOBAs) are a form of village savings and loan institution with a conservation focus. A joint program by Frankfurt Zoological Society, an international NGO operating in the ecosystem, Tanzania National Parks and the Serengeti District Council first introduced the COCOBA model to three of the study villages in 2009 with the goal of providing a conservation-friendly income alternative for bush meat hunters. These banks are comprised of 15 to 30 community members who collectively contribute shares to a common bank. Members are able to take low-interest loans to support conservation-friendly (or neutral) income generating activities (Kaaya & Chapman, 2017, Walelign *et al.*, 2019). COCOBAs place emphasis on elements of self-help initiatives, community capacity building and local resources mobilization, community project ownership, and joint management of natural resources.

These banks proved to be very popular. As the loanable capital of the groups grew, so did demand for participation. Additional groups were trained in the pilot villages in 2011, and in 2012 more groups were formed in additional villages. During the time our study was conducted, 14 COCOBA groups were formed in five of the 8 study villages. The introduction and expansion of these credit associations provides a unique opportunity to examine whether the introduction of a COCOBA group influences bushmeat consumption.

METHODS

The primary method we use to measure consumption of bush meat, domestic meat, and livestock holdings is through data generated from a seven-day dietary recall survey administered each month to a sample of households in Western Serengeti (Rentsch & Damon, 2013, Fischer *et al.*, 2014, Rentsch & Packer, 2014). Eight villages were selected in 2007 from a pool of 26 villages located in Bunda and Serengeti Districts and immediately bordering Serengeti National Park, Ikorongo-Grumeti Game Reserves or Ikona WMA, while bordering no other study village (Figure 1). This area is known for the high prevalence of bush meat hunting, at least partially due to its proximity to abundant migratory wildlife. An initial panel of 132 households were recruited within the study villages using a stratified random sampling method, where households were selected from four randomly selected sub-villages within each village (villages typically contain 6-10 sub-villages) (Rentsch & Damon, 2013). After introducing the study to household members 18 years or older, we obtained informed consent for participation in the study. Participating households were given the option of withdrawing from the study at any time.

Tracking consumption patterns is an important and feasible way to assess how households respond to interventions aimed at improving socio-economic conditions, and therefore to measure the success of the interventions themselves. Longitudinal data, in this case over a seven year period, provides deeper insight into consumption behavior than cross-sectional data, and is a potentially effective and relatively low-cost tool for monitoring legal and illegal natural resource use.

Our dietary recall survey contained questions about the kind of protein consumed in the previous week (beef, goat, sheep, chicken, pork, fish, dagaa, bush meat, or eggs), how the meat was prepared (dried or fresh), where it was acquired, how many kilograms were cooked, and the price per unit for the meat. The questionnaire also included basic demographic information about the number of people in the household. In-depth questions about the health and number of livestock owned by each household were included to monitor livestock health and serve as a proxy for relative household wealth over the course of the study. We recruited two enumerators from each village to assist with data collection and trained them extensively in the use of the questionnaire and conduct of ethical research. The enumerators visited each household on roughly the same date each month (generally within plus or minus one calendar date) to assist the households with the recall questions. Throughout the study, research staff typically visited the enumerators every second month to review and collect the questionnaires and address any issues or concerns. Households which moved away or which chose to remove themselves from the study were not replaced, though the data up to that point were included in the analysis. For the analyses presented here, we utilized 8,304 observations from October 2007 to November 2013.

All statistical tests were conducted in R (R package version 3.3.1). We used a panel data analysis to conduct a two-way, fixed effect linear model for each household's unique identification value and each temporal observation (Croissant & Millo, 2008). We generated a series of fixed-effect linear models, with number of reported meals consumed per household per week, as the dependent variables. Our goal was to test the relative importance of livestock ownership on consumption of key protein sources, not to include all the variables which may have the

Table 1: Two-way, fixed effect linear regression

	Bush meat	**Beef**	**Chicken**	**Milk**
Livestock died in prev. month	-0.01 (-0.02, -0.000)	0.001 (0.003)	-0.002 (-0.01, 0.002)	-0.004 (-0.02, 0.01)
Cows owned	0.002 (0.0004, 0.004)	-0.000 (-0.001, 0.001)	-0.000 (-0.001, 0.0005)	0.01 (0.003, 0.01)
Chicken owned	-0.001 (-0.003, 0.001)	-0.001 (-0.002, 0.0003)	0.001 (0.0003, 0.002)	.002 (-0.001, 0.004)
Bushmeat price	-0.04 (-0.06, -0.01)	0.01 (-0.01, 0.03)	0.01 (-0.003, 0.02)	0.02 (-0.03, 0.06)
Household size	-0.04 (-0.05, -0.04)	0.01 (-0.01, 0.03)	-0.01 (-0.01, -0.01)	-0.1 (-0.12, -0.10)
Rainfall	-0.01 (-0.03, 0.02)	0.003 (-0.01, 0.02)	0.001 (-0.01, 0.01)	0.01 (-0.04, 0.05)
Observations	5,240	5,220	5,241	5,236
R2	0.03	0.01	0.01	0.1
Adjusted R2	-0.01	-0.03	-0.03	0.05
F Statistic	28.6*** (df = 6; 5033)	5.8*** (df = 6; 5013)	12.7*** (df = 6; 5034)	79.2*** (df = 6; 5029)

highest explanatory power. We ran this model with bush meat meals reported per household per week as the dependent variable, as well as with beef, chicken and milk, since each would be expected to be influenced by the ownership of livestock (particularly cows and chickens), according to our hypothesis (Table 1).

To compare the influence of the presence of COCOBA groups within the village, we used the same model, but introduced a dummy variable for each village from the first month when at least one COCOBA group was operational in that village (Table 2).

Table 2: Effects of COCOBA in village on bush meat consumption two ways effects Within Model

Dependent variable	**Bush meat meals per household per week** **β (95% confidence interval)**
Bush meat price	-0.05 (-0.07, -0.02)
Household size	-0.04 (-0.05, -0.04)
Rainfall	-0.01 (-0.04, 0.02)
Cattle owned	0.002 (0.0003, 0.004
Chickens owned	-0.001 (-0.003, 0.001)
Large livestock lost (lag)	-0.01 (-0.02, -0.001)
COCOBA (y/n)	-0.12 (-0.18, -0.05)
Observations	5,240
R^2	0.04
Adjusted R^2	-0.004
F statistics	26.24 (df = 7; 5032)

We employ the following panel regression model to examine the effect of livestock production, rainfall, and village micro-credit organizations on bush meat consumption:

y_i=β_0+β_1 X_vt+β_2 HHSZ_it+β_3 RAIN_vt+β_4 No.Cows_it+β_5 No.Ckn_it+β_6 LostLS_(i,t-1)+β_7 CreditOrg_vt+α_i+γ_t+ϵ_it

where X is the price of bush meat in village v in time t, HHSZ is household size for household i, RAIN is the SPI index at the village level, No.Cows is the number of cows owned by the household, NoCkn is the number of chickens owned by the household, Lost LS is the number of large livestock lost in the previous month, and CreditOrg is an indicator variable that equals 1 if the village has at least one COCOBA group. To account for time invariant household level effects (e.g. cultural norms of the household or preferences for bush meat) we include a household level fixed effect,α_(i), as well as a month-year fixed effect,γ_t, that accounts for effects during time t that affects all households.

RESULTS AND DISCUSSIONS

Households in the study area rely heavily on bush meat to meet their protein needs. Fig.2 reports that bush meat is one of the most commonly consumed protein sources with an average household consuming 2.3 meals of bush meat per week during the sampling period (2007-2014). This represents a weekly expenditure of approximately 4,300 Tanzanian shillings on bush meat per household. With an estimated 21,927 households living in the sample area (National Bureau of Statistics, 2012), the total value of bush meat purchased within communities is estimated at more than USD $1.1 million in total value.

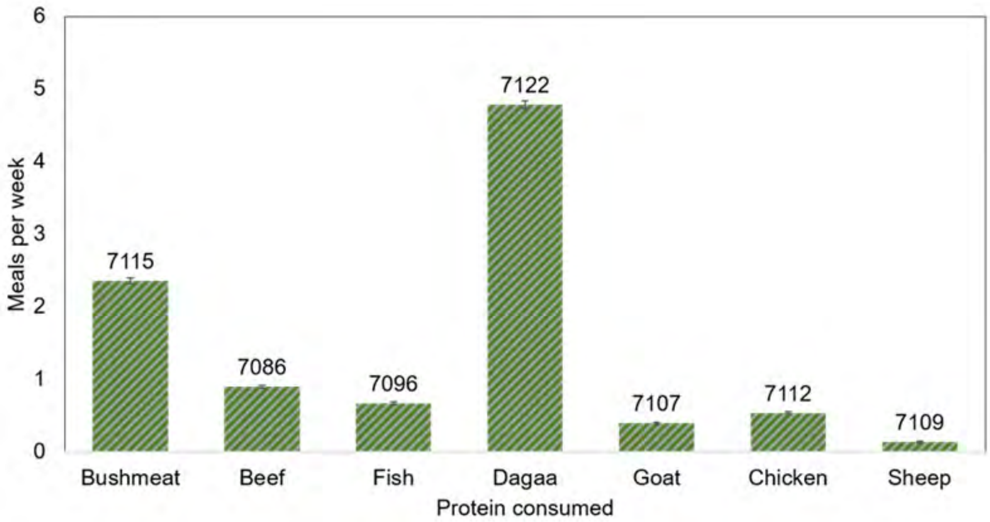

Figure 2: Average meals consumed per household per week (Sample size listed on top of bars)

Protein Alternatives and Bush meat Consumption

Overall, reported cattle ownership increased throughout the study period (2007-2014), with the average household increasing cattle ownership by 3.15 cows (41% average increase). In Table 1, we see that an increase in cattle ownership by one head of cattle increases bush meat meals consumed per households per week by 0.002, but surprisingly, has no detectable effect on beef meals consumed. Milk consumption also increases with cattle ownership (β=0.01, 95% CI: 0.003 to 0.01). While the effect may appear relatively small (β= 0.002), it suggests an impact of an additional approximately 0.104 meals per year per household per additional cow owned. With this sample representing more than 130,000 households across just the two Districts containing the study villages (National Bureau of Statistics, 2012), an increase of even a few cows per household per year can result in significantly more wildlife off-take. Increases in chicken ownership per household increases consumption of chicken by the household, but had no influence on the consumption of bush meat. Interestingly, households which lost large livestock (cattle, goats or sheep) in the previous month (eg: experienced a financial shock) were less likely to consume bush meat in the current time period, though this effect was not significant for consumption of any other protein sources.

To understand these results requires an understanding of the dual role of livestock in rural agrarian economies in East Africa. Large livestock (cows, goats and sheep) typically serve as a form of savings account in these rural agrarian communities. As households increase wealth, they typically increase large livestock (cows, sheep & goat) holdings, only selling them when in need of cash, rather than raising them for meat production and selling them at a fixed time. Cows are often milked for home consumption, as indicated by the observed increase in milk consumption per additional cow owned, but rarely slaughtered at home for beef. In this context, it is not entirely surprising that we found that as households increase livestock ownership, bush meat consumption rose as well. This relationship is consistent with previous studies (Rentsch & Damon, 2013) which indicate that bush meat is highly expenditure elastic. Shocks to the household economy in the form of loss of large livestock result in a significant decrease in protein consumption the following time period, with a particularly large effect on bush meat consumption. This is further evidence that wealth held in cattle strongly affects the consumption of bush meat.

Alternative livelihoods for hunters

COCOBA savings and loan groups were introduced to villages which were known to have a high number of bush meat hunters (based on anti-poaching arrest records), and these villages were found to have initially higher rates of bush meat consumption. When the fixed-effect regression model (Table 2) was run introducing a dummy variable from the time when the first COCOBA group was established in each village, we found that households decreased reported consumption of bush meat by 0.12 meals per person per week after the introduction of the micro-credit group within the village (Fig. 3).

the mechanism linking the introduction of COCOBAs and an observed reduction in bush meat consumption is somewhat unclear. One possibility is that alternative income streams for bush meat hunters limit the supply of bush meat as the hunters become occupied by other economic activities. As such we would observe an increase in the local price of bush meat and a decrease in the quantity demanded, which was not observed. The magnitude of the effect of COCOBAs on decreasing bush meat consumption was considerably greater than that of increasing livestock ownership on higher bush meat consumption. This finding offers hopeful evidence to conservation practitioners who wish to reduce bush meat consumption, and may help explain why overall trends in household bush meat consumption declined.

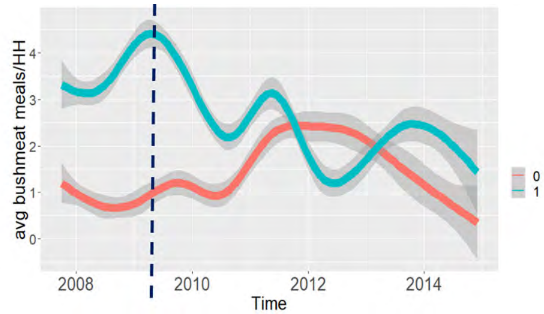

Fig. 3. Bush meat consumption over time before and after introduction of COCOBA micro-credit groups in study villages

CONCLUSION

Bush meat consumption is an important protein source for households living adjacent to protected areas in the Greater Serengeti Ecosystem, and plays a large role in the local economy. The market for bush meat is driven by factors which change over time. Understanding how changes in bush meat consumption are affected by the dynamics of household economies can help identify conservation strategies that can successfully reduce bush meat consumption without compromising food security or income generation for local communities. The unique nature of our longitudinal dataset allows us to investigate how different socio-economic and environmental changes influence bush meat consumption over time.

We find that cattle are both a source of protein and vehicle for household savings. As household cattle ownership (wealth) increases, beef consumption does not increase, but bush meat consumption does. This is a particularly concerning discovery given the rates of increase in cattle ownership in western Serengeti. These results support the findings that households make decisions to consume bush meat based on a number of factors, not just access to alternative (non-bush meat) protein sources (Rentsch & Damon, 2013). Strategies aimed at reducing demand for bush meat by increasing household domestic livestock holdings as a means of providing protein alternatives are therefore likely to fail.

The relative price of beef to bush meat may strongly influence consumption patterns, however, the relationship between consumption of beef and the production of cattle is not strongly correlated. This is likely due to the dual role that livestock plays in the household economy as a source of both food and savings. Increasing availability of beef can reduce beef prices and demand for bush meat, but this is unlikely to be achieved through marginal improvements in household cattle production. In fact, our findings suggest that increasing household livestock ownership has no effect on consumption of beef, but significantly increases demand for bush meat.

Bush meat consumption, and by extension, bush meat hunting, are part of a suite of decisions which households make on a regular basis. Households may choose to purchase and consume bush meat when prices are cheaper than alternative protein sources, and consume more of it when their savings (livestock) are secure. Likewise, access to alternative income, either through micro-credit initiatives, or through productive agriculture, may result in fewer hunters, and thus less supply of bush meat locally, thus increasing the local price of bush meat.

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ECOSYSTEM SERVICES: SOCIAL, CULTURAL AND ECONOMIC VALUES OF ELEPHANTS FOR COMMUNITY'S LIVELIHOODS IN THE SERENGETI ECOSYSTEM

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ABSTRACT

Ecosystems provide goods and services that are basic needs for human wellbeing. Social, cultural, traditional and economic values are considered as part of ecosystem services from biodiversity within a given ecosystem. Despite these important roles, the exact ways in which different ecosystem services, with their rich biodiversity resources including large mammals act to enhance community's livelihood are not clear. This study aimed at establishing a comprehensive understanding of the social, cultural and economic values of the elephant as a keystone species to community's livelihoods within the Serengeti ecosystem. The study was conducted in four districts of Ngorongoro, Serengeti, Bariadi and Meatu in northern Tanzania. A total of 12 villages were surveyed through questionnaire surveys where a total of 446 respondents were interviewed. Focus group discussions, Key informant information and literature review were also used for verification of information. Majority of respondents (38%, N = 444)declared that, elephant has no any social value, while 36% did not know whether elephant has any social value. Few had reported that elephants have social values in the communities as they are used for recreation (15%), tourist attraction (6%) and for education purpose (5%). The negative perception on low values of elephants were related to losses incurred from elephant damages. Communities within Serengeti ecosystem understand key values accrued from elephants that include spiritual values among tribes that use elephant as a totem species despite losses and damages incurred through the species. It is therefore important that conservation education programmes to protect elephants in the ecosystem is enhanced among the local communities. Engagement of villagers in conservation programmes and initiating conservation based alternative income generating projects in areas prone to human-elephant conflicts may enable communities to easily recognize the values and services of protecting elephants in the country.

Keywords: community's livelihoods, ecosystem services, elephants, Serengeti ecosystem

INTRODUCTION

Ecosystem Services are defined as the benefits provided by ecosystems that contribute to human welfare (Wallace, 2007). Ecosystems provide goods and services that are basic needs for human wellbeing such as food, water, shelter fuel (Díaz *et al.*, 2019; Veldhuis *et al*., 2019). Largely it provides regulatory services that include among others pest and disease, biochemicals and climate regulations, water and nutrient cycling. Cultural, traditional ecological knowledge, recreational and spiritual values, are also considered among the ecosystem services provided to human beings (Wangai *et al.*, 2019). Through ecosystem services, biodiversity plays a major role in improving human well-being. It provides subsistence and economic goods for people (Carpenter *et al*., 2006; Díaz *et al*., 2019; Jiaoa *et al.*, 2019; Wangai *et al*., 2019). Ecosystem services such as cultural services (for example, religious values, tourism, education and cultural heritage) are key and important services linked to the presence of biodiversity in any ecosystem. However, for many years the exact ways in which different ecosystem services with their rich biodiversity resources act to enhance community's livelihood are not well known to many people.

In Africa, humans have lived alongside elephants and the two have shared many things from nature that are in common. Therefore the relationship between humans and elephants has a very long history, (Mackenzie & Ahabyona, 2012; Skarpe et al., 2014). Both species share complex social behavior such as birth, as well as a communication through myriad and in mourning systems (Wittemyer & Getz, 2007; Wittemyer *et al*., 2007; Mackenzie & Ahabyona, 2012; Shannon *et al*., 2013; Ihwagi *et al*., 2018)

The African elephant (*Loxodonta africana*) act as 'flagship' species in African protected ecosystems. It is a highly charismatic animal that can serve as a rallying point for conservation; capturing the attention of people from all over the world. African elephants play important role in ecology, as well as in socio-economic and cultural aspects. Ecologically, elephants are among the megafauna (Owen-Smith, 2010) and considered as ecosystem engineers (Mamboleo *et al.,* 2017). In tropical forests, elephants play an important ecological role by creating clearings and gaps in the canopy that allow tree regeneration and provide habitats for gap-specialized species (Stephenson, 2007; Kohi, 2013). They are important dispersal agents for seeds from a number of tree species and also affect the cover and distribution of miombo and acacia woodlands (Dudley, 2000). In savanna ecosystems, elephants play a major role in maintaining open grasslands with few trees. They also help shape woodland structure of extensive areas and amplifying browse heterogeneity in African savanna (Hakansson, 2004; Wasser et al., 2010; Kohi *et al*., 2011). These entire functions together act as a support for healthy ecosystems. Therefore, loss or reduction in numbers of elephants can affect the integrity of the ecosystems and their services, including the social and economic values provided by the species.

Elephants contribute to socio-economic benefits largely through the use of non-consumptive values such as ecotourism (viewing and photographing)(Bandara & Tisdell, 2003). On one hand, elephants generate significant returns from wildlife-based tourism (Kyando *et al*., 2017). On the other hand elephants contribute to negative economic impact to people living adjacent to protected areas, as they damage crops and properties and sometimes causing injuries or death or when people try to prevent them from such damage (Bandara & Tisdell, 2003; Hariohay *et al*., 2019). The primary reason for the clash between humans and elephants is the accelerating human population growth in the vicinity of protected areas, which have resulted into a dramatic reduction of elephant habitats through destruction, fragmentation and isolation (Newmark, 2008; Hariohay *et al*., 2017).

Despite the perceived negative interactions of African elephants to communities, there is a growing interest on understanding the positive interactions (both socially, culturally as well as the economic values) of elephants to community livelihoods adjacent to protected areas. In the Serengeti ecosystem, an increasing human population poses threat to conservation of elephants and other natural resources at large (Veldhuis *et al*., 2019). Many efforts have been done on addressing Human Elephant Conflicts (HEC), however, social, economic, and cultural values of communities can currently affect the perceptions of elephant conservation in areas adjacent to the network of protected areas.

Research studies have been conducted on the negative sides of HHC, but very little has been done on the positive interactions. As such,there are less data and comprehensive information on social, economic, and cultural values of elephants and their positive contributions to the community's livelihoods residing within the Serengeti ecosystem. Therefore, this study focused on filling up the knowledge gaps in order to provide positive responses to support sustainable conservation of elephants in the ecosystem.

Objectives

The main objective of this study was to establish a comprehensive understanding of the social, cultural and economic values of elephants to community's livelihoods within the Serengeti ecosystem. The specific objectives included; 1) Assessing the social, cultural and economic values of elephants for community's livelihoods and, 2) Providing suitable community-based approaches that can contribute to improved elephant conservation in the ecosystem.

MATERIAL AND METHODS

Study area

The survey was conducted in 12 villages in the 4 districts of Bariadi, Meatu, Ngorongoro and Serengeti (figure 1) within the Serengeti Ecosystem. It is a highland savannah region with thorn tree woodlands and plains ranging from approximately 900 to 1,500 metres above sea level. The average annual rainfall ranges between 500 and 1200 mm, declining towards the Park boundary and increasing towards Lake Victoria in the western Serengeti (Campbell & Hofer, 1995). The monthly average temperatures fluctuate between 25^{o}C to 32^{o}C (Campbell & Hofer, 1995). Main economic activities in the area is agro-pastoralism and pastoralism (Nyahongo, 2007). The ecosystem also supports other key economic activities such as tourism, sport hunting in the game reserves and game controlled areas. Charcoal production, agricultural activities, mining, logging and other forms of land use also take place in the unprotected parts of the ecosystem (Kaaya & Chapman, 2017; Tarimo *et al.,* 2017; Veldhuis *et al.*, 2019).

Data collection

Data were collected using a semi-structured questionnaire from a total of 444 households in the districts of Ngorongoro, Meatu, Bariadi, and Serengeti (Fig. 1). Twelve villages , namely Oloipiri, Makundusi, Robanda, Oldonyowasi, Nyamakendo, Olorieni, Sapa, Mwauchumu, Matongo, Mwajidalala, Salaliya and Ng'hanga (Fig. 1). The villages were selected with the main criterion that the village should bewithin Serengeti ecosystem located in the distance <10 km (Makundusi, Robanda, Nyamakendo, Sapa, Mwauchumu, Matongo, Salaliya, Ng'hanga), 11-20 km (Oloipiri), 21-30 km (Olorieni)and > 30 km (Oldonyowasi) from the protected area (PA) boundary. We hypothesized that, people from villages closest to PAs have greater knowledge of social, cultural, and economic values of elephants in the area.

Prior to the interviews, the main purpose of the study was explained to village executive officers or chairman. Permission for conducting interviews was then granted. For this study, the household was regarded as a sampling unit. Respondents above 18 years old were randomly selected for interview. A total of 37 respondents were randomly selected from village registers and interviewed in each village making a total of 444 respondents from 12 villages. Any member of the household 18 years old and above was interviewed during the survey if the head of the family or wife was not present. The purpose of this was to reduce the biases in the selection of households and to ensure that the sample was representative. The interview was conducted under the assistance of local translators. The information recorded included the socio-demographic variables (tribe, age, gender, education level, occupation and wealth) and the knowledge on the social (tourist attraction, social gathering, education), cultural (rituals. medicine, symbol for certain clan), traditional (spiritual believes, related to human beings) and economic (employment, market for local products, support for local micro-finance bank) values of elephants in communities adjacent to the park. The questionnaires were prepared in the English language and were translated into Swahili language during the interview.

Data analysis

Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS

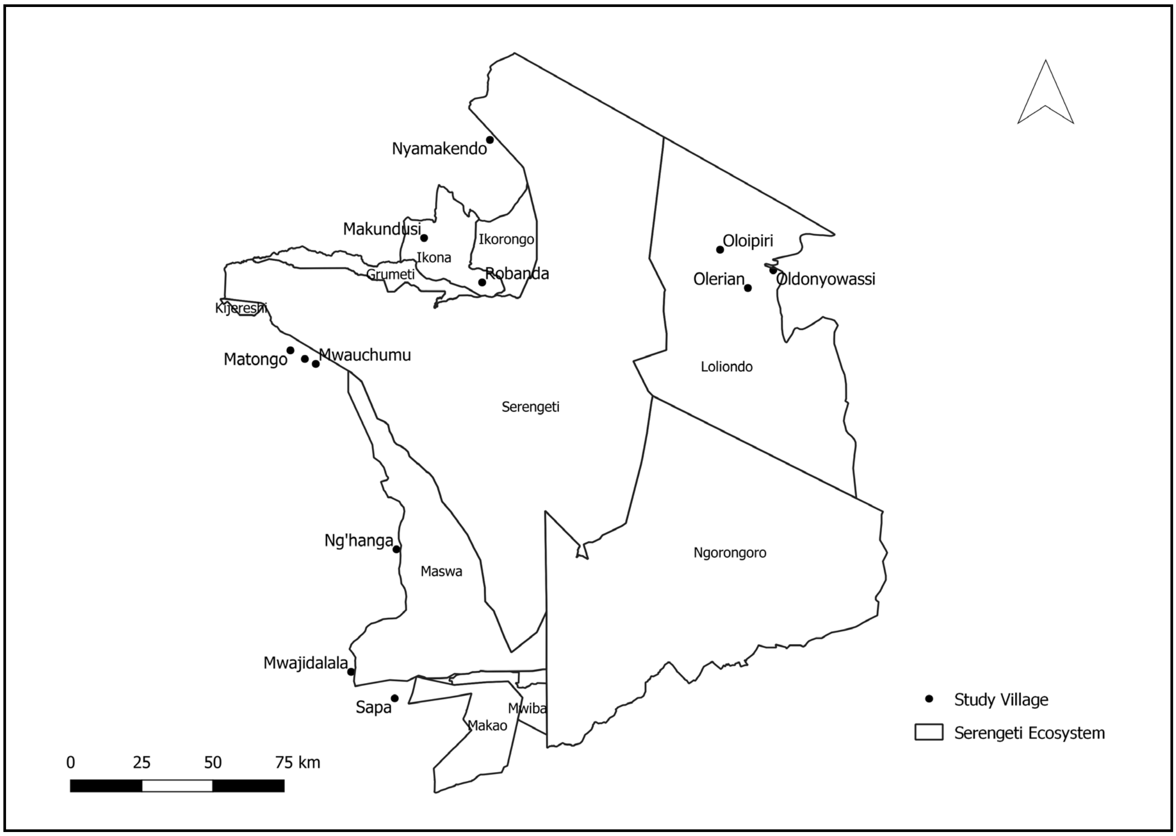

Fig. 1. Study area map, indicating the locations of study villages in the Serengeti Ecosystem

version 24, NY, USA). Descriptive statistics were used to summarize the questionnaire response data. Pearson's chi-square analyses were performed to determine the differences in the independent variables that explain knowledge about social, cultural, traditional and economic values of elephant in communities adjacent to the park. Furthermore, generalized linear models (GLM) were used to determine the factors that contributed most to statistical significance in relation to independent variables The significance level was set at $P < 0.05$.

RESULTS

Socio-economic characteristics of the respondents

A total of 444 household's heads were interviewed out of which 57.7% were males. Majority of respondents were in age class of 18-32 years (31.3%) followed by 33-47 years (30.4%), 48-62(20.5%) and > 62 years (17.8%). Almost one thid had never been to school (30.2%), while the majority had attained primary education (61.7%), finally a few had been to secondary education (5.4%) and college education (2.7%). The main dominant tribes in the study area were Sukuma (43.5%), Maasai (29.5%), Kurya (13.1%), Ikoma (7.7%) and others (6.3%).

Majority (53.6%, N = 444) were born within the surveyed villages while 46.4% had immigrated into villages. Reasons for immigrating were reported to be marriages (22.9%), land for settlements (8.9%), cultivation (18.2%),land for livestock (2.9%), business (5.3%), employment (4.3%), followed parent (1.8%), ethnic conflicts (0.4%) and other reasons combined (29.3%).

Most of the respondents (70.7%) lived closer to the PA boundary ≤10 km, followed >30 km (10.4%), 11-20 km 9.7% and 21-30 km (9.2%). The main social economic activities of the respondents were livestock keeping (60.1%), cultivation (37.0%), business (1.8%), employment (0.7%) and others (0.5%).

Social and economic values

Generally, the majority of the respondents (63.0%, N = 444), did not know that elephants have any social value. A few reported that elephants have social values in the communities as they are used for recreation (16.5%), tourist attraction (6.0%) and for education purposes (7.6%), social gathering (3.8%), or support from investors (3.2%). Furthermore, respondents with primary education level reported more social values from elephants than other education classes ($\chi2 = 26.02$, df = 18, $P = 0.031$) (Figure2).

Out of 444 respondents, only 13.06% reported to have tested elephant bush meat. Respondents gave different reasons for not tasting bush meat; that included among others, not easily accessible (35.9%), traditional believes (24.4%), the elephant is considered like a human being (14.9%), not used to elephant bush meat (11.1%), bad smell (7.0%), religious believes (4.4%) and health problems related (2.2%). A linear regression analysis revealed that distance, tribe and sex were the significant variables in explaining the observed 21% variation in consumption of elephant meat (Table 1).

High price was a key factor explaining the difficulties underlining consumption of elephant meat for those who reported to have consumed and or tested it. The price of elephant bush meat increases with the distance from the PA boundary, with highest price in the distance > 30 km and prices were statistically significant different between distances, the two sexes and among tribes (Table 2).

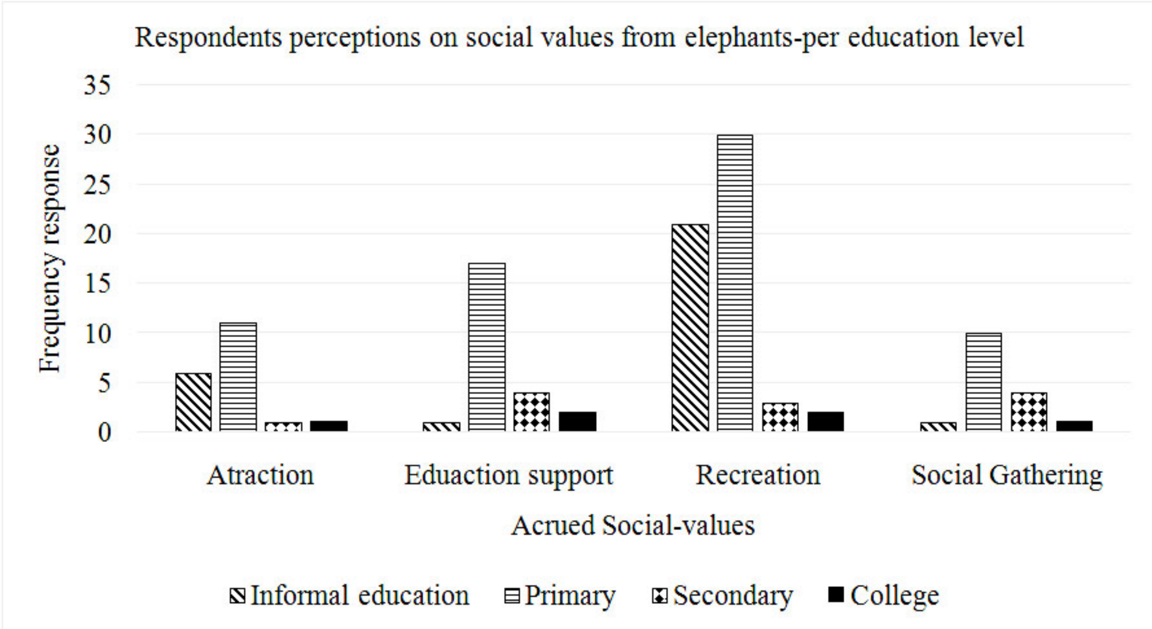

Fig. 2. Social values as indicated by different education group levels

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Table 1: Six factors that might predict differences in bushmeat consumption. In the table we present significant factors from a linear regression model with bushmeat consumption as a dependent variable and four independent variables: distance, age, sex, tribe education level and sources of income. B: Estimate, SE: standard error and P: p-value.

Independent variables	Unstandardized Coefficients		Standardized Coefficients		
	B	SE	Beta	t	P
(Constant)	2.71	0.40		6.75	**<0.0001**
Distance from the PA boundary to the village center	-0.32	0.11	-0.21	-2.80	**0.005**
Tribe	0.27	0.09	0.22	2.88	**0.004**
Sex	0.15	0.05	0.15	3.15	**0.002**
Age	0.11	0.09	0.07	1.19	0.233
Education Level	-0.11	0.17	-0.04	-0.62	0.536
Major sources of income	0.08	0.13	0.04	0.62	0.536

a. Dependent Variable: Reasons for not testing elephant bushmeat

Table 2: Mean comparison of price (TZS) /kg/piece of elephant bushmeat between village, age groups, sex, tribe and districts of respondents.

Parameter	Attribute	Mean	N	SD	F	df	P-value
Distance	≤10 km	1666.67	24	996.37	23.98	3	<0.0001
	11-20 km	1357.14	14	234.40			
	21-30 km	3000.00	15	0			
	>30 km	3600.00	5	894.42			
Age	18-32	2000.00	23	839.37	1.03	3	0.387
	33-47	1888.89	18	993.44			
	48-62	2454.55	11	1254.08			
	> 62	2500.00	6	1483.08			
Sex	Male	2574.07	27	1025.66	12.24	1	0.001
	Female	1693.55	31	891.41			
Tribe	Ikoma	1346.15	13	240.19	6.52	4	<0.0001
	Kurya	1875.00	4	946.49			
	Sukuma	3500.00	3	1802.78			
	Maasai	1125.00	4	250.00			
	Others	1346.15	13	1046.12			
District	Serengeti	1409.09	22	479.00	16.28	3	<0.0001
	Ngorongoro	2411.76	34	980.65			
	Meatu	5000.00	1	0			
	Bariadi	4000.00	1	0			

A generalized linear model was used to examine the factors explaining observed differences in social value, with six independent variables (Table 3). Four independent variables (distance, tribe, age and residency of respondent) were found to be statistically significant in explaining the observed differences in social value of elephants. Education and sex of respondents were not significant (Table 3).

Economic values

A generalized linear model was used to examine the factors explaining observed differences in economic value (employment, market for local products, support for local micro-finance bank) with six independent variables (Table3). Four independent variables distance, tribe, residency and education level were found to be statistically significant in explaining the observed differences in economic value of elephants. Age and sex of respondents were not significant (Table3).

Traditional belief

Out of the 444 respondents, 32.0% reported that the elephant has traditional values. These values includes:-traditionally respected as the original of some clans (symbol) in the community and respected to humans (41.0%, n = 140), some parts such as tails are used during ritual ceremonies (12.0%), traditional medicines (i.e. elephant liver is used to treat liver related diseases in human beings)(31.0%) and spiritual believes(16%).

More Kurya (67.0%), followed by Ikoma (20.0%) and Sukuma (13.0%) had reported elephant to be associated with traditional believes as an ancestor of some clans. Of those who reported that some elephant parts are used during ritual and traditional ceremonies, Kurya were the majority (38.0%), Ikoma (27.0%), Sukuma (23.0%) and Maasai (12.0%). Generally, respondents declared that, though elephants do not directly contribute tangible economic benefits to communities, however they play significant values among those whose cultures are rooted into elephants as clan origins and use of some parts for rituals and medicinal purposes. Some important socio-cultural values across tribes in the study villages are described in table 4 below.

Table 3: Six factors that might predict differences in social (tourist attraction, social gathering, education) and economic (employment, market for local products, support for local microfinance bank) values of elephants. In the table we present parameter estimates from a generalized linear model with social values and economic values as a linear response variable and six explanatory variables: distance, age, sex, tribe, residency, and education. B: Beta, SE: standard error, χ^2 = Chi-Square and P: p-value, * (P <0.01), ** (P<0.001) and *** (P<0.0001).

	Social values			Economic values		
Parameter	B	SE	Wald Chi-Square	B	SE	Wald Chi-Square
(Intercept)	5.80	1.25	21.60***	9.23	1.25	54.55***
[Distance= ≤ 10 km]	-0.77	1.08	0.50	-4.49	1.09	17.11***
[Distance=11-20 km]	-4.99	0.39	161.96***	-1.28	0.48	7.15**
[Distance=21-30 km]	-4.01	0.47	71.59***	-1.07	0.39	7.62**
[Age=18-32 years]	-0.16	0.18	0.73	-0.17	0.19	0.84
[Age=33-47 years]	-0.35	0.18	3.90*	0.01	0.18	0.01
[Age=48-62 years]	0.36	0.18	3.95*	0.02	0.19	0.01
[Sex=Male]	-0.17	0.12	1.77	-0.08	0.13	0.41
[Tribe=Ikoma]	-2.14	0.39	30.27***	-1.10	0.33	11.00**
[Tribe=Kurya]	1.41	0.26	29.37***	0.68	0.27	6.52*
[Tribe=Sukuma]	-0.82	0.24	12.03**	0.98	0.24	16.03***
[Tribe=Maasai]	0.48	1.07	0.20	-3.67	1.07	11.72**
[Residency=Born in the village]	0.26	0.13	4.05*	0.62	0.13	21.85***
[Education level=Never been to school]	0.28	0.39	0.52	-1.22	0.39	9.67**
[Education level=Primary]	0.46	0.38	1.46	-1.14	0.38	9.01**
[Education level=Secondary]	-0.12	0.44	0.08	-1.18	0.44	7.31**

Table 4: Elephant parts used by different tribes in Serengeti ecosystem, response from Focus Group discussions.

Tribe	Parts used	Uses	Description
Maasai	Dung	Medicinal	Cures chest problems pains and Asthma for people: Smoking elephant dung will help to reduce the pain and also open the air passage of the sick person. Also, mix and make a strong mixture strain and give to sick person to drink. Cures Foot and mouth disease for livestock-dry dung when they are bunt the heavy smoke when inhaled.
	Liver	Medicinal	Roasted and dried, and then consumed to treat asthma. Treat liver problems in human
	Fat	Medicinal	Filler for medicine, paste boiled into liquid oil and drunk to treat heart problems, chronic weakness, tuberculosis, asthma
	Bones	Medicinal	Used to cure swellings (grounded powder after bunt)
	Skin	Medicinal	Small piece worn by sick person eliminate the diseases.
	Placenta	Rituals	When a small part is dried and worn it bring good luck and when tied around the house brings blessings
	Tusks	Rituals	A small piece when worn and mixed with some herbs is used for protections from any danger
		Ceremonial and commercial values	Small piece is sold and as ornament
Kurya "Wakira clan"	Live animal	Rituals	they call elephant "Inchugu" is highly respected as their "ancestor"-god of Wakira
Kurya-Wanyabasi clan	Live animal	Food	Elephant meat
Ikoma "Machaba clan"	Live animal and Tusks"	Rituals/Totem species	Elephant called as "Machaba" and they consider elephant as their "God"
Kurya	Fat	Medicinal	Treat chest problems also for massaging to reduce bone pains
	Dung	Medicinal	Smoked to reduce chest problems
	Liver	Medicinal	When dried, its powder used to treat liver related problems to human beings
	Tusk	Commercial	Selling of elephant tusks by poachers
	Meat	Food	Some clans consume elephant meat
Sukuma	Live animal	Cultural belief	Is associated to human being " human being Ancestor"
	Dung	Medicinal	Treat asthma, chest pain and stomach ulcers
	Liver	Medicinal	Treat human liver problems
	Tusk	Commercial	Selling, small pieces are worn as ornaments

A generalized linear model was used to examine the factors explaining observed differences in traditional belief with six independent variables (Table 5). Four independent variables; distance,age, tribe and residency of respondents were found to be statistically significant in explaining the observed differences in traditional belief of elephants. Education level and sex of respondent were not significant (Table 5).

Table 5. Six factors that might predict differences in traditional believes (spiritual believes, related to human beings). In the table we present parameter estimates from a generalized linear model with traditional believes as a response variable (binomial error distribution and logit-link function) and six explanatory variables: village, age, sex, tribe, residency and education level. B: Beta, SE: standard error, χ^2 = Chi-Square and P: p-value

Parameter	B	SE	Hypothesis test		
			χ^2	df	P
(Intercept)	10.70	1.22	76.28	1	<**0.0001**
[Distance= ≤ 10 km]	-2.08	1.08	3.72	1	0.054
[Distance=11-20 km]	-4.77	0.26	328.98	1	**<0.0001**
[Distance=21-30 km]	-5.04	0.26	386.91	1	**<0.0001**
[Age=18-32 years]	0.30	0.18	2.81	1	0.094
[Age=33-47 years]	-0.58	0.17	11.43	1	**0.001**
[Age=48-62 years]	-0.36	0.18	4.10	1	**0.043**
[Sex=Male]	-0.17	0.12	2.15	1	0.143
[Tribe=Ikoma]	-3.89	0.30	163.96	1	**<0.0001**
[Tribe=Kurya]	-3.30	0.27	150.92	1	**<0.0001**
[Tribe=Sukuma]	0.05	0.25	0.03	1	0.855
[Tribe=Maasai]	-3.87	1.07	13.20	1	<**0.0001**
[Residency=Born in the village]	0.29	0.13	5.18	1	**0.023**
[Education level=Never been to school]	0.44	0.37	1.39	1	0.238
[Education level=Primary]	0.33	0.36	0.86	1	0.354
[Education level=Secondary]	-0.34	0.41	0.67	1	0.414

DISCUSSION

The reasons for more male domination are rooted in the traditional norms and cultures, that, females are not spoke's persons at house hold level, unless the husband has given permission to do or, the husband has passed away, a woman can respond as a head of house hold.

The study indicated that, majority of respondents reported to have seen no social value 38% (N = 446), and or did not know whether elephant has any social value 36%. The negative perceptions with regard to values accrued from elephant that were expressed by majority of respondents are associated with increased damages done by elephants.

The close positive relationship between people and wild animals is rooted into human kind origins. Use of totems among different African tribes demonstrated the close relationship between people, wildlife and the environment where they live. This study revealed that despite damages encountered through elephants such as crop raiding, injury and death to people and property, still some traditional values are appreciated by communities. Use of animal parts depends on how the clan or tribe is linked to a specific animal species. In this study, Kurya and Ikoma would not harm an elephant, as they use it as a totemic species and they have been preventing elephant from not being killed and rescuing from dangers.

Different culture practices through use of animals (Kideghesho, 2008), like how to make youth become heroes for rescuing their totems is common in many African cultures. The spiritual value of elephant is well pronounced for example in Ikoma tribe where elephant has been used as a Totem species for "Machaba clan" and for Kurya tribe the "Wachaba clan" who have been using elephant traditionally as an ancestor, but also as a way of protecting the environment.

Elephant Task (Machaba in Ikoma Machaba-clan) is believed as "god-totem" for the clan. This is a very strong belief by the Waikoma. They believe that worshiping the "Machaba (elephant tusk)" you can request anything and you will get a positive response. It is believed that the Ikoma tribe when practicing sacrifices using "Machaba", all problems become solved. They are still using "Machaba" up to now for sacrifices during difficulties/crisis such as hunger/famine, disease outbreaks, war, prolonged drought (they request rain), during conflict mitigation between families or tribes/clans and between age classes or even gender.

However, it was reported that, with the recent change in life style, less respect is paid to elephants, which has resulted into killing of elephants even by some Ikoma and Kurya people for retaliatory which has resulted into change of behavior of elephant they are now aggressive than before and thus more conflicts.

The few respondents reported to know elephant social-economic values being used for recreation, tourist attraction and for education purposes. Variations were observed among villages, tribes and education level of respondent. The differences in positive response were associated to the presence of tourism investments and social services received through tourism activities example at Robanda and Makundusi villages that receive good shares from both Ikona WMA and Grumeti Fund. The social-cultural and economic values of a certain species vary across tribes in the study area. Like elsewhere in many African countries, these values are always rooted into strong norms and taboos, and these are passed from one generation to another (Kioko, 2015).

Spiritual, social and cultural values reported by respondents in this study had indicated a high level of relationship between tribes under study and elephants. These results are complemented by the studies of Kideghesho (2008) and Kioko (2015). Evidences on how the species body parts have been used across tribes for rituals, medicine, food and also for economic gains was expressed among the communities within the ecosystem. Although most of these cultural values have been eroded among many tribes, however there is still strong historical connections with those clans that have been worshiping elephant, for example Ikoma-"Machaba clan" still maintainthe respect to elephant. To some extent, the continuation of this has provided protection to the elephant in their area. Furthermore, Maasai in Loliondo, where the study was conducted, are still closely connected to their traditions and have a strong feeling that elephants are respected species among age classes of the entire Maasai tribe and thus, they are still co-existing with elephants in their areas with minimal problems. These positive Socio-cultural and economic values of elephants have been also reported in other countries, for example products such as bones of Asian elephants (Elephas maximus) were used by kings for important decisions making in China (Wertz R, 1998). Use of elephant tusk powder by Maasai to treat swellings in human body, is related to some tribes of the Yoruba in Nigeria who use the tusk to treat rheumatism (Soewu, 2008).

Communities within the study area despite reporting less direct values from elephant, still have indicated that, elephant need to be conserved and that if educated on current values it will change their perceptions. They indicated that, following huge damages done by elephants, voluntary conservation groups have been formed in several villages adjacent Serengeti National park for preventing the damages using indigenous knowledge. Similar initiatives were shown by Asian, people who were willing to pay for conservation of the Asian elephants (Elephas maximus) not because of positive socio-cultural and economic benefits they received, but because of their understanding that the elephants will continue to exist for the future generation (Bandara&Tisdel, 2003) .

CONCLUSION AND RECOMMENDATIONS

Communities within the Serengeti ecosystem understand the key values that are accrued from elephants, despite of the losses incurred from the species. It is therefore recommended that, awareness raising to communities residing adjacent the ecosystem on values and the status of elephants worldwide as well as ongoing threats is important. Integrating indigenous knowledge and natural sciences is important for sustaining elephant populations across the region and improving livelihoods. Also, engagement of communities, specifically youth in law-enforcement efforts coupled with some tangible incentives would help in protecting elephants in the ecosystem.

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QUANTIFYING WATER REQUIREMENTS OF AFRICAN UNGULATES THROUGH A COMBINATION OF FUNCTIONAL TRAITS

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ABSTRACT

Surface water is a key resource for both wildlife and livestock and its spatial and temporal distribution is important for understanding the composition of large herbivore assemblages in savannas. Yet, the extent to which ungulate species differ in their water requirements remains poorly quantified. Here, we infer the water requirements of 48 African ungulates by combining six different functional traits related to physiological adaptations to reduce water loss, namely minimum dung moisture, relative dung pellet size, relative surface area of the distal colon, urine osmolality, relative medullary thickness and evaporation rate. In addition, we investigated how these differences in water requirements relate to differences in dietary water intake. We observed strong correlations between traits related to water loss through dung, urine and evaporation, suggesting that ungulates minimize water loss through multiple pathways simultaneously, which suggests that each trait can thus be used independently to predict water requirements. Furthermore, we found that browsers and grazers had similar water requirements, but browsers are expected to be less dependent on surface water because they acquire more water through their diet. We conclude that minimum dung moisture contents is an ease and useful way to determine differences in water requirements and an important tool for predicting changes in herbivore community assembly resulting from changes in surface water availability.

Keywords: Climate change, evaporation, water loss, surface water dependence, dietary water.

INTRODUCTION

Variability in temperature and rainfall patterns is increasing, with consequent effects on resource availability for herbivores across. In semi-arid regions, a reduction in dry season precipitation is expected, which will likely trigger more recurrent and severe droughts (Engelbrecht *et al.*, 2015). Droughts will not only influence herbivores through changes in food availability, but also directly through decreased surface water availability (Gaylard *et al.*, 2003). Most ungulates in dry lands and savanna ecosystems require access to surface water to maintain body fluid homeostasis. However, we lack a general understanding of how ungulates differ in their water requirements; how management authorities can predict herbivores' surface water dependence using functional trait, and whether and how changes in surface water availability will affect the community composition of savanna ungulates.

During the dry season, water-dependent herbivores are constrained by their minimum fundamental frequency of drinking (Smit, 2011; Valeix, 2011). Dry season distributions of herbivores in relation to surface water (distance to water) are therefore commonly used as a measure of their surface water dependence (Gereta *et al*, 2009; Kihwele *et al.*, 2018; Owen-Smith, 2015). However, herbivore distributions are confounded by other factors such as predation risk and food availability, so that distance to water is not a reliable indicator of water dependency. It is now possible to measure drinking frequency from higher resolution GPS data to quantify the degree of surface water dependence (Curtin *et al.*, 2018), but it is logistically not feasible to collar many individuals species. Therefore, we propose to use a combination of functional traits to quantify herbivore water requirements as an alternative approach.

In order to deal with periods of water shortage, ungulates have developed a suite of ecological, physiological and behavioral adaptations to conserve body water (Turner *et al,* 2010). These adaptations allow water loss to be reduced through different channels (Fig. 1) to cope with changes in water availability (Cain *et al*, 2006). For example, some arid-adapted species exhibit a relatively large surface area to volume ratio of the spiral and distal colon that allows them to reabsorb more water from their dung (Maloiy, 1973a). Similarly, a relative thick kidney medulla supports juxtamedullary nephrons with long loops of Henle to concentrate urine and enable arid-adapted species to reduce urinal water loss. However, it remains to be investigated whether different water conservation traits are associated.

Here, we quantified water requirements for 48 African large mammalian herbivore species using six functional traits. We combine data on dung properties collected in Serengeti National Park and Gorongosa National Park with physiological and ecological traits from published studies. We then explore the relations between minimum dung moisture, dung pellet size, distal colon area, urine osmolality, medullary thickness and evaporation rate to find the best indicator(s) for water requirements of mammalian herbivores. Subsequently, we investigate the relationships between our predicted water requirements with herbivore feeding types, phylogeny and classifications of surface water dependence based on literature assessment. Last, we investigated whether species water requirements relate to the amount of water obtained through their diet by comparing our predicted water requirements to dietary water intake using published data on oxygen isotopic enrichment.

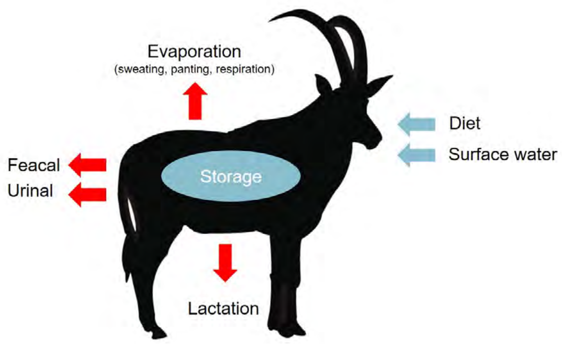

Fig. 1. Primary components of the water balance in ungulates. Red arrows represent water loss while blue ones represent water gain. Some species have specific adaptations to store water (blue circle)

METHODS

We quantified water dependence of 48 herbivore species through combining data obtained from previously published studies with data measured in the field. We used 6 functional traits as indicators of water dependence: minimum dung moisture content, relative dung pellet size, relative distal colon area, urine osmolality, relative medullary thickness and evaporation rates. We subsequently tested our predictions for a subset of 11 ungulates using experimentally quantified water requirements. We extended our dataset with data on dung moisture and fresh pellet size in Serengeti National Park and Gorongosa National Park that allowed us to study seasonal variation in dung moisture. Furthermore, we used isotopic oxygen enrichment (see below) as a measure of dietary water intake to investigate which species could decrease their dependence on surface water by using alternative sources of water.

Field data collection

Data were collected in 2018 in both wet (Mar-May) and dry season (Aug-Oct) in Serengeti National Park (SNP), Tanzania, and supplemented with dry season (Oct) data from Gorongosa National Park (GNP), Mozambique. Samples of 13 herbivore species (impala (*Aepyceros melampus*), hartebeest (*Alcelaphus buselaphus*), wildebeest (*Connochaetes taurinus*), topi (*Damaliscus lunatus*), plains zebra (*Equus quagga*), Thompson's gazelle (*Eudorcas thomsonii*), giraffe (*Giraffa camelopardalis*), waterbuck (*Kobus ellipsiprymnus*), elephant (*Loxodonta africana*), Grant's gazelle (*Nanger granti*), common warthog (*Phacochoerus africanus*), buffalo (*Syncerus caffer*) and eland (*Tragelaphus oryx*) were collected for dung moisture content and, of these, 11 species for dung pellet size in Serengeti National Park. In Gorongosa National Park, we collected data on both dung moisture and pellet size from seven species: sable antelope (*Hippotragus niger*), oribi (*Ourebia ourebi*), bush pig (Potamochoerus larvatus), southern reedbuck (*Redunca arundinum*), nyala (*Tragelaphus angasii*), bushbuck (*Tragelaphus scriptus*), and greater kudu (*Tragelaphus strepsiceros*). In both parks, drinking water is abundant during the wet season and becomes scarce as the dry season reaches its peak.

Dung moisture content

In addition to our dung moisture data from SNP and GNP, we obtained dung moisture data for the dry season and captive animals through our literature search. We then correlated the dung moisture data from the wet season (sufficient water) against the dry season (water limited) collected in Serengeti and the dung moisture of captive individuals (ad libitum) against the dry season dung moisture (water limited) data of our overall database and fitted linear regressions to investigate the plasticity of this trait.

Relative pellet volume

Pellet volume (V) was calculated from the three dimensions (LxWxH) assuming an ellipsoid shape: V = 4/3 x pi x 0.5L x 0.5W x 0.5H. To correct for species body size, we divided pellet volume by the body mass of each species, because arid-adapted species have smaller pellets than predicted for their body mass (Coe & Carr, 1983).

Relative distal colon area

Data on the dimensions of the intestines for 15 ruminant ungulates were acquired from (Woodall & Skinner, 1993).

Urine osmolality

Urine osmolality data was obtained from (Beuchat, 1990; King, 1983; Penzhorn, 1988), which all represent maximum urine osmolality values.

Relative medullary thickness

Data on the relative thickness of the medulla (RMT) was taken from (Cloete & Kok, 1986) and calculated from published values on medullary thickness (MT) and kidney volume (KS) following: RMT = MT / KS * 10, where KS is computed as cube root of the product of the three size dimension: (L x W x H)0.33 (Greenwald, 1989; Beuchat, 1990). Hippo's (Hippopotamus amphibius) lack central medulla and thus have little capacity to concentrate urine (Beuchat, 1996).

Evaporation

Data on evaporation rates were obtained from controlled experiments in climate rooms (Maloiy, 1973b).

Water requirements

The same experiments yielded unique data on water requirements (Maloiy & Hopcraft, 1971) through gradually reducing drinking water to a point where animals were able just to maintain their weight at about 85% of the initial levels, which was then presented as the minimum water requirements of those species.

Predicting water requirements based on the functional traits

We then used the six different traits to predict the water requirements of 48 ungulates for which we had at least data for one of the traits. To obtain a single currency for water requirements, we predicted the dung moisture from the regressions between dung moisture and the other functional traits. These estimates of inferred dung moisture from different traits were then averaged for each of the three different pathways: dung (dung moisture, relative dung volume, relative distal colon areas), urine (urine osmolality, relative medullary thickness) and evaporation (relative evaporation) and rescaled between 0 and 100, representing a scale from deficient to excessive water requirements. An overall ranking is then presented using the mean of the three predictions linked to the three channels.

Dietary water intake

Isotopic oxygen enrichment was used as an indicator of the amount of water obtained through diet relative to drinking surface water (Kohn, 1996). δ18O values in plant leaves are higher because evaporation enriches the remaining water in the heavy isotope 18O relative to source water (Blumenthal et al., 2017) and δ18O values in large herbivores can thus be used as an indicator of the source of water (surface water vs diet).

Feeding type

Feeding types were distilled from (Kingdon *et al.*, 2013), yielding 6 feeding type categories: obligate grazers (GRO), variable grazers (GRV), and distal colon area are constant throughout the seasons and provide secondary indices for the capacity to prevent water loss through dung. Herbivore species differed significantly in these physiological and ecological traits related to water loss through dung. Minimum dung moisture content showed strong correlations with relative distal colon area and with relative pellet volume. However, the non-ruminant ungulates common warthog (*Phacochoerus africanus*) and plains zebra (*Equus quagga*) did not follow the general trends with relative pellet volume and had relatively larger pellets than the ruminants. We did not have data on distal colon area for non-ruminants so we could not investigate whether they follow the trends we found for the ruminants. No significant differences were found between feeding types for minimum dung moisture content (ANOVA: F6, 36 = 2.0, P=0.08), relative pellet volume (ANOVA: F3,10 = 1.2, P=0.34) or relative distal colon area (ANOVA: F4,11 = 1.1, P=0.37).

variable browsers (BRV), obligate browsers (BRO), frugivores (FRU) and generalists (GEN). Livestock species were not included in the analyses of feeding types.

Water dependence classification

Classification of surface water dependence was taken from (Hempson *et al*, 2015), which aggregated data from Kingdon et al. (2013).

Data analysis

All statistics were performed in R software version 3.5.1 (R 2018). Basic ANOVAs and linear regressions were used for all analyses.

RESULTS

Comparison between different indicators of water loss through dung

All three indicators of water loss through dung were highly correlated (Fig 2). Dung moisture represents the actual water loss but varies based on water availability, while relative pellet size

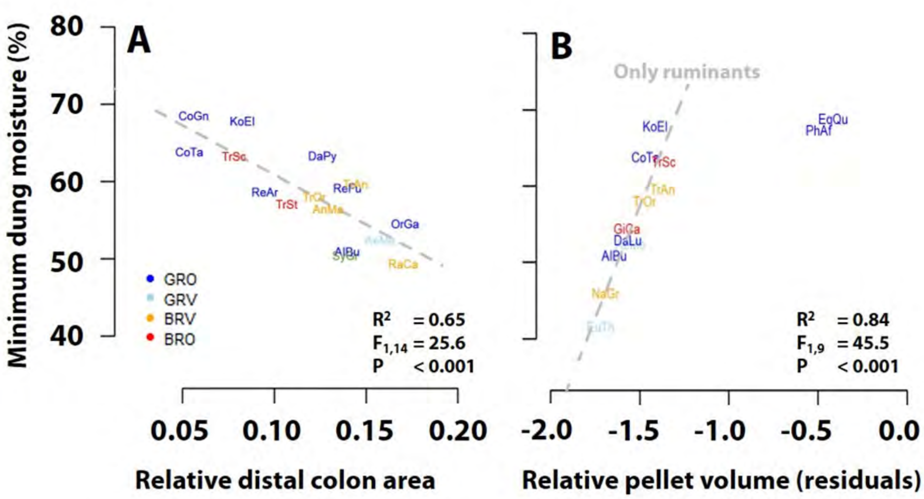

Fig. 2. The relationships between different indicators of water loss through dung Correlation of minimum dung moisture against relative distal colon area (A) and relative dung pellet volume (B). Dashed grey lines represent linear regression models that only represent ruminants (excluding EqQa and PhAf in (B)). Colors identify feeding types. Abbreviations represent the two first letters of the genus and species names.

Relationships between indicators of the different pathway of water loss

We observed strong correlations between indicators of the three different channels of water loss (dung, urine and evaporation), with the most robust relationship between dung moisture and urine osmolality. Our results indicate that animals with dry dung have concentrated urine (Fig. 3A), greater relative medullary thickness (corrected for kidney size, Fig. 3B) and low relative evaporation rates (corrected for body mass, Fig. 3C), so that arid-adapted herbivores prevent water loss through all pathways simultaneously. Urine osmolality (ANOVA: $F_{4,15} = 1.8$, $P = 0.18$), relative medullary thickness (ANOVA: $F_{4,10} = 2.9$, $P=0.08$) and evaporation rates (ANOVA: $F_{3,8} = 0.2$, $P = 0.87$) did not differ between feeding types.

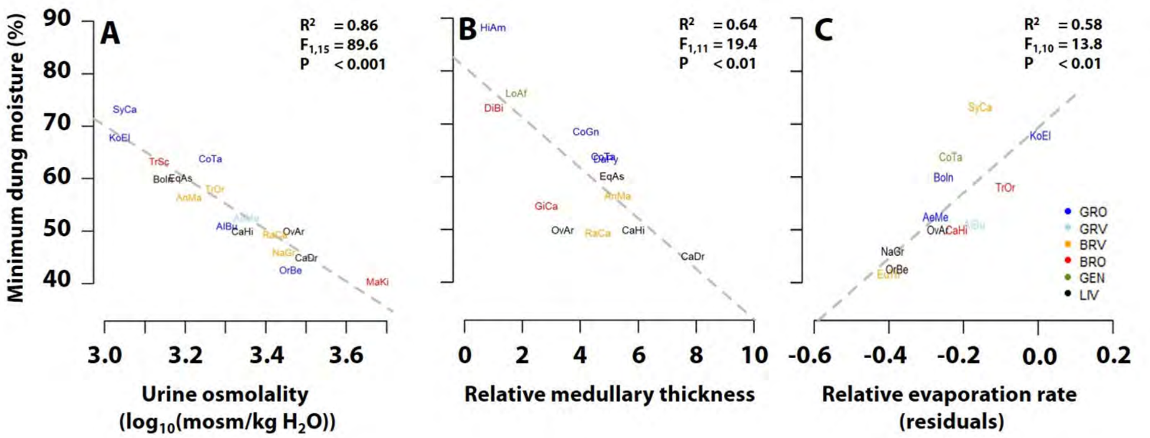

Fig. 3. Relationships between indicators of water loss through dung, urine and evaporation. Correlation of minimum dung moisture against urine osmolality (A), relative medullary thickness (B) and relative evaporation rate (C). Dashed grey lines represent linear regression models. Colors identify feeding type of wild herbivores. Livestock species are presented in black. Abbreviations represent the two first letters of the genus and species names

Relating water loss indicators to water requirements

Composite indices of water loss through dung (combining dung moisture, relative pellet size and distal colon area into a single indicator), urine (combining urine osmolality and relative medullary thickness) and evaporation all predicted the experimentally measured water requirements of large herbivores well (Fig. 4), with evaporation explaining most variation. Combining these indices into a single indicator had similar predictive ability of the experimentally measured water requirements (Fig. 4D).

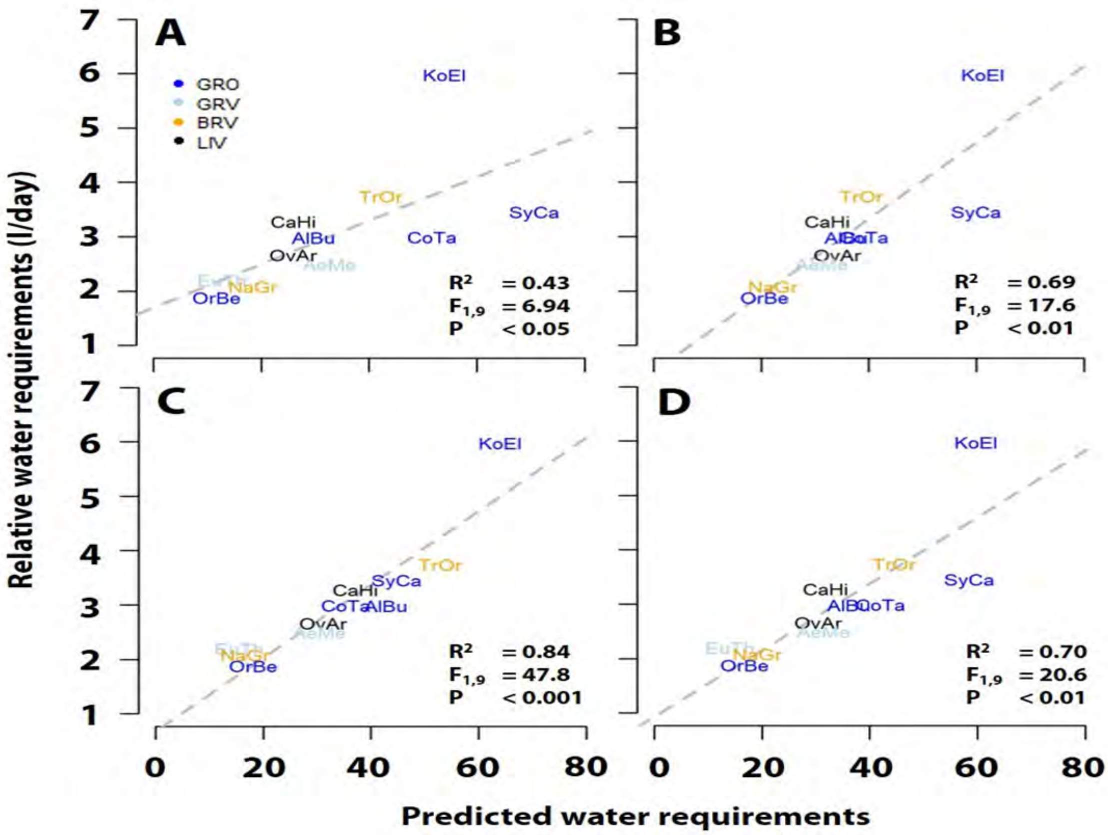

Fig. 4. Relationship between measured water requirements of 11 ungulates and their predicted water requirements based on composite indicators of water loss through dung (A), urine (B), evaporation (C) or a combination of them (D). Dashed grey lines represent linear regression models. Colors identify feeding type of wild herbivores. Livestock species are presented in black. Abbreviations represent the two first letters of the genus and species names (see Table S1)

Relating water loss indicators to water requirements

Composite indices of water loss through dung (combining dung moisture, relative pellet size and distal colon area into a single indicator), urine (combining urine osmolality and relative medullary thickness) and evaporation all predicted the experimentally measured water requirements of large herbivores well (Fig.4), with evaporation explaining most variation. Combining these indices into a single indicator had similar predictive ability of the experimentally measured water requirements (Fig. 4D).

Predicting water requirements for the African ungulate guild

Our predicted water requirements based on combined indicators of water loss through dung, urine and evaporation show a wide variety of water requirements among 48 African ungulates, with Kirk's dik-dik (Madoqua kirkii) having the smallest and hippo (*Hippopotamus amphibius*) the largest water requirements (Fig. 5). The variation of our prediction for water requirements is in general agreement with the categories of surface water dependence classifications (ANOVA: $F3, 44 = 6.9$, $P < 0.001$). Water requirements did not differ between feeding types (ANOVA: $F_{5,42} = 1.5$, $P = 0.20$), even when we excluded non-ruminants (ANOVA: $F_{5,33} = 1.1$, $P = 0.36$). However, we did find a strong phylogenetic signal of water requirements (ANOVA: $F_{15,35} = 7.3$, $P < 0.001$). Non-ruminants, Bovinae (Bovini and Tragelaphini) and Reduncini showed higher water requirements in general, while the gazelles (*Antilopini*), horse-like antelopes (*Hippotragini*) and dwarf antelopes (*Neotragini*) are predicted to exhibit low water requirements.

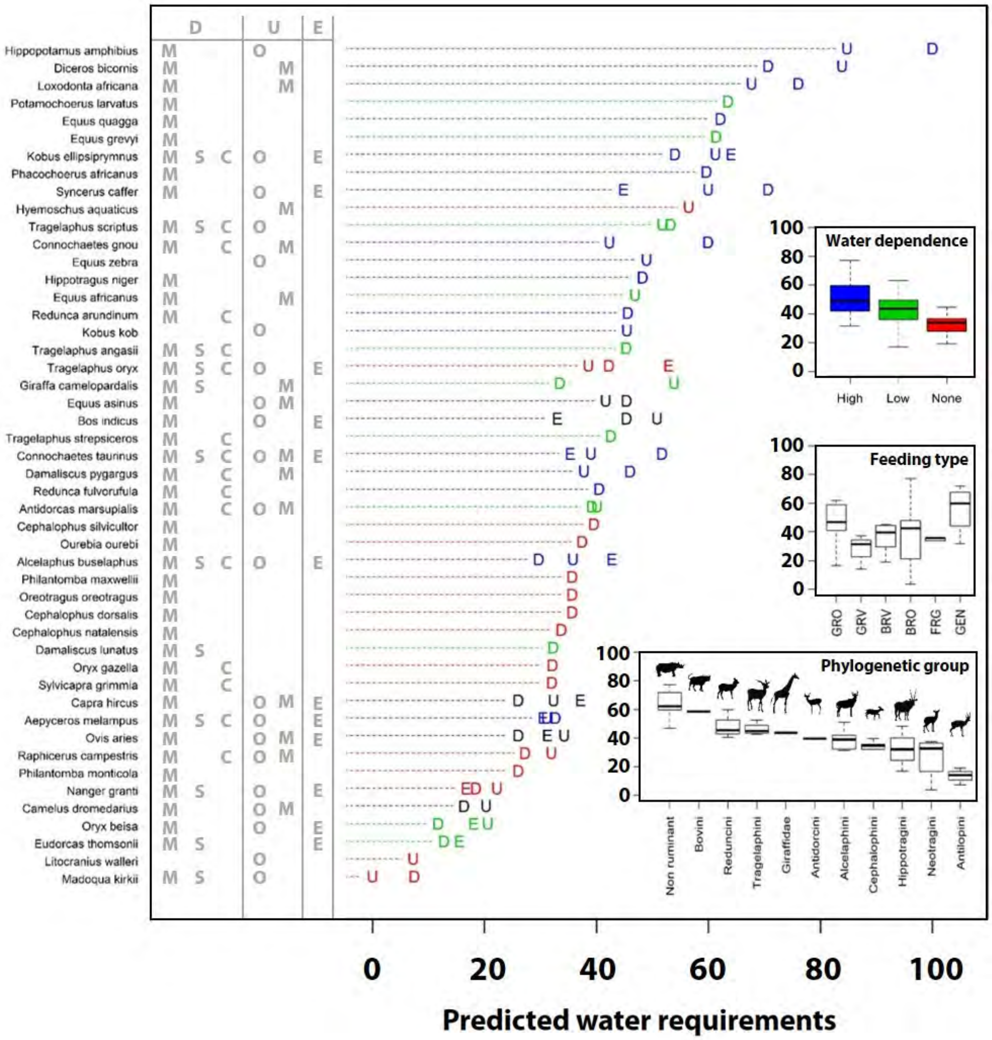

Fig. 5. Predicted water requirements of 48 African ungulates based on composite indicators of water loss through dung (D), urine (U) and evaporation (E). Colors represent water dependence classifications based on literature assessment with three classes: none (red), low (green) or high (blue). Livestock species are presented in black. Insets display the variation of water-dependent classification (top), feeding type (middle) and phylogenetic group (bottom). Data availability of the 6 indicators per species are presented in the columns on the left with dung moisture content (M), relative pellet size (S) and relative colon area (C) as indicators of water loss through dung (D); urine osmolality (O) and relative medullary thickness (M) as indicators of water loss through urine (U) as well as water loss through evaporation (E).

Relationships between dietary water intake and water requirements

Water obtained through food relative to drinking generally decreased with an increase in our predicted water requirements (Fig. 6), suggesting that species adapted to arid conditions do not only reduce water loss, but also increase dietary water intake, thereby reducing their dependence on surface water. Feeding type did not significantly affect dietary water intake across all ungulates (ANOVA: $F_{4, 15} = 1.69$, $P = 0.20$). However, there were significant differences when we limited the analyses to ruminants only (ANOVA: $F_{3, 9} = 9.4$, $P < 0.01$). Obligate browsers (BRO) obtained more water from their diet than obligate grazers (GRO; $P < 0.01$), while variable grazers (GRV) and variable browsers (BRV) showed intermediate dietary water intake but marginally insignificant from obligate browsers ($P = 0.06$ and $P = 0.09$ respectively), probably due to their low sample size. Greater kudu (*Tragelaphus strepsiceros*) and Grevy's zebra (*Equus grevyi*) showed significantly higher oxygen isotope enrichment than would be expected based on their predicted water requirements, suggesting that these species can compensate for their relatively high water requirements through dietary water acquisition making them less dependent on surface water than expected.

DISCUSSION

We quantified water requirements for 48 species of African ungulates by combining six functional traits related to water loss. We found these traits to be highly correlated and accurately predicted the experimentally measured water requirements of a selection of ungulate species, suggesting each single trait is a valuable indicator of ungulate water requirements. African ungulates varied widely in their water requirements and in general, water-independent species obtain more water through their food relative to drinking thereby reducing their dependence on surface water. In general, our predicted water requirements were in line with classifications based on literature assessments. Furthermore, our results suggest higher water requirements for non-ruminants, which is in agreement with the finding that artiodactyls evolved and speciated under arid conditions (Strauss *et al.*, 2017). Altogether, our results show great potential for using functional traits to predict ungulate water requirements, specifically for large herbivore species assemblages.

The strong correlations between minimum dung moisture and all other indicators of water loss provide evidence that herbivore species reduce water loss through multiple pathways simultaneously, such that species producing dry dung also produce highly concentrated urine (Maloiy, 1973). However, some of these traits are more plastic than others. Dung moisture was higher in the wet season than dry season and a higher moisture content was observed in captive individuals provided with free access to drinking water than free-ranging individuals, which is in agreement with previous work. Not surprisingly, urine osmolality also varies with water availability and evaporation varies with both water availability and ambient temperature. The flexibility of these traits appear to be an important physiological and ecological adaptation to (seasonal) changes in water availability (Woodall & Skinner, 1993) and thus provide a more sensitive and plastic variable to assess water requirements in temporally and spatially heterogeneous landscapes. In contrast, anatomical adaptations such as the dimensions of the kidney and intestine, and consequently dung size, are likely to be more constant and may thus provide a better indication of the capacity to conserve water. We therefore suggest that dung moisture is an easy-to-measure (flexible) index of the hydration state of African ungulate species, while relative dung size is an easy-to-measure (static) index of the species' capacity to conserve water.

Our interpretation of the data must be tempered by some limitations. First, we do not have a complete list of traits measured for all species under the same environmental conditions. Our predicted water requirements for some species are based on a single trait measure, which make those predictions less reliable. Second, our data is biased towards ruminant herbivores. Although non-ruminants followed the general patterns for the correlations between minimum dung moisture, urine osmolality and relative medullary thickness, we do not have data on intestine dimensions or evaporation rates for these species. Furthermore, plains zebra and warthog (non-ruminants) were strong outliers to the general trend between minimum dung moisture and relative dung pellet volume (Fig. 2B). Zebra and warthog have relatively large dung pellets which provide a small surface area for water resorption through the colon. Future work should thus aim to augment the trait dataset, specifically for non-ruminants, to improve the accuracy of the predictions and the robustness of our conclusions about the generality of the observed patterns. Third, the isotopic oxygen enrichment that we used in our analysis is a valuable tool but has important limitations. For example, fruits do not exhibit oxygen enrichment (Kohn, 1996) thereby reducing the reliability of the method for species with a high percentage of succulent fruit in their diet. This calls for further research to investigate the proportional contribution of each food component on the overall water budget of the species. Despite these limitations, our study shows great potential for using functional traits to predict ungulate water requirements.

While our predicted water requirements generally were in line with classifications based on literature assessments, there were some intriguing inconsistencies between the two. We predicted relatively lower water requirements for some species (beisa oryx, Thompson's gazelle, impala and hartebeest) and higher water requirements for others (eland, Grevy zebra, bushpig and bushbuck). Deviations towards lower predicted water requirement could result from species using habitats closer to water for other reasons than water requirements that led observers to believe the species was water dependent. For example, impala are generally found close to water and are therefore often classified as water dependent even though their water requirements have been shown to be low (Maloiy, 1973). Water dependence classifications of hartebeest are ambiguous; some authors place them in the water-bound group whereas others classify them as water independent (Woodall & Skinner, 1993). Our prediction is based on functional traits and thus is less confounded by ecological factors such as food availability or predation risk. Our deviating predictions towards higher water requirements likely result from the difference between water requirements and surface water dependence. Species with higher water requirements can reduce their dependence on surface water through increased intake of preformed water. For example, eland are generally classified as water-independent (Woodall and Skinner, 1993), even though experiments have shown they have about the same water requirements as buffalo. Eland could increase independence of surface water by means other than water conservation such as the selection of succulent food. Increased intake of preformed water could thus decrease surface water dependence regardless of their basic water requirements and might be of particular importance for species that are closely related to more water-dependent lineages (Bovinae, Equidae, Suidae).

In general, there was a negative correlation between isotopic oxygen enrichment and water requirements, with those species relying on preformed water in their diet scoring lower on our predicted water requirements based on functional traits. Overall, species with lower water requirements are thus also less dependent on acquiring water through drinking. Nevertheless, specific species such as greater kudu and Grevy's zebra, recognized for occupying drier areas, are predicted to have relatively high water requirements but reduce surface water dependence through behavioral adaptation such as increased dietary water intake and thus can decrease surface water dependence if sufficiently high moisture forage is available. Also, ruminant browsers showed significantly higher dietary water intake than ruminant grazers, even though feeding type did not affect their water requirements, suggesting that browsers are less dependent on acquiring water through drinking than grazers. This is in agreement with the suggestion that browsers acquire a substantial amount of water from their diet, potentially making them less dependent on surface water. Altogether, our results suggest that the reduction of surface water dependence though increased intake of preformed water can be very important, is difficult to quantify and very species specific. Detailed investigations of the proportional contribution of each food component to the overall water budget of each species are required.

CONCLUSIONS AND RECOMMENDATIONS

The expected changes in climate and land use, compounded by an increase in the frequency and intensity of drought, will further exacerbate the limited water supply in savanna ecosystems, especially during the late dry season. As such, the quantification of herbivore water requirements is vital to guide management and conservation of herbivores. We conclude that functional traits are a great tool to predict ungulate water requirements. Each of these traits provide specific information about ungulate water balance and their combination provides a convenient estimate of water requirements. Expanding this approach to a more complete dataset and a greater range of species will further elucidate the role of water requirements in structuring African ungulate communities.

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EFFICACY OF LAND USE DESIGNATION IN PROTECTING HABITATS IN THE MIOMBO WOODLANDS: INSIGHTS FROM TANZANIA

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ABSTRACT

Loss of natural landscapes surrounding major conservation areas compromise their future and threaten-long-term conservation. We evaluate the effectiveness of fully and lesser protected areas within Katavi-Rukwa and Ruaha-Rungwa ecosystems in south-western Tanzania to protecting natural landscapes within their boundaries over the past four decades. Using a time series of Landsat satellite imageries of September 1972, July 1990 and September 2015, we assess the extent to which natural habitat has been lost within and around these areas mainly through anthropogenic activities. We also test the viability of the remaining natural habitat to provide connectivity between the two ecosystems. Our analysis revealed that while fully protected areas remained intact over the past four decades,lesser protected areas lost a combined total area of about 5,984 km^2 during that period which is about 17.5% of habitat which was available in 1972. We also find that nearly 3,380 km^2 of natural habitat is still available for connectivity between the two ecosystems through Piti East and Rungwa South Open Areas. We recommend relevant authorities to establish conservation-friendly village land use plans in all villages surrounding and between the two ecosystems to ensure the long-term conservation of these ecosystems.

Keywords: anthropogenic activities, habitat conversion, land cover, land use, miombo woodland

INTRODUCTION

About 15% of the land worldwide is currently designated as protected areas (henceforth "PAs") for biodiversity conservation (Juffe-Bignoli *et al*., 2014), and efforts are underway to further extend this to 17% of all terrestrial land and 10% of coastal and marine areas by 2020 (Di Minin & Toivonen, 2015). These efforts indicate the importance that countries and the international communities attach to the role PAs play in preserving natural landscapes and reducing biodiversity loss overlong-term (Dudley, 2008; Serra *et al*., 2008; Wyman & Stein, 2010; Schulz et al., 2010; Gao & Liu, 2010;

Gibbs *et al*., 2010; Lung & Schaab, 2010; Leroux *et al*., 2010; Azadi &Hasfiati, 2011; Estes *et al*., 2012; Bailey *et al*., 2016). However, poverty, population pressures and escalating demand for natural resources compounded by conflicting national policies, poor governance and weak institutions (Rao *et al.*, 2009), have influenced the ability of PAs to fulfil their role (Brashares *et al*., 2001; Dwivedi *et al.*, 2005; Shalaby & Tateishi, 2007; Bakr *et al.*, 2010). While the expansion of PAs coverage and their contribution to nature conservation is well recognised (Pimm *et al*., 1995; Baillie *et al.*, 1996; Myers *et al*., 2000; Bruner et al., 2001; Rodrigues *et al.*, 2004a,b; Jenkins & Joppa, 2009; Leveringtonet al., 2010; Machumu & Yakupitiyage, 2013), there is increasing argument surrounding PAs' effectiveness in protecting biodiversity loss due to the wide-spreading anthropogenic activities within and outside their boundaries (Pimm & Raven, 2000; DeFrieset al., 2005; Stoner *et al.*, 2007a; Gardner *et al*., 2007; Bradshaw et al., 2009; Ahrends *et al*., 2010; Gibson et al., 2011; Laurance *et al.*, 2011, 2012; Ghimire & Pimbert, 2013; Clark *et al.*, 2013; WWF, 2016).

Tanzania maintains a variety of PA categories which allow different levels of legal restrictions on resource use including fully protected areas (henceforth "FPAs") (constituting 17% of the land surface) comprising of national parks (only allow photographic tourism), game reserves (permit tourist hunting), forest reserves (some permit selective logging) and the Ngorongoro Conservation Area (NCA) which is similar to national parks but allows cattle grazing by indigenous Maasai pastoralists (MNRT, 2007; Stoner *et al.*, 2007a). The rest of the PAs (constituting 18% of the country's land surface) are considered as lesser protected (henceforth "LPAs") and include Game Controlled Areas (GCAs) and Open Areas (OAs) where extractive resource use is permitted under license (MNRT, 2007). Wildlife Management Areas (WMAs) comprise Tanzania's newest protection category that aims to promote wildlife management at the village level by allowing rural communities and private land holders to manage wildlife on their land for their own benefit and devolving management responsibility of the settled areas and areas outside unsettled PAs to rural people and the private sector (USAID, 2013; WWF, 2014).

Despite having a variety of PA categories in place, there has been little effective evaluation of how well the different classes prevent habitat loss although efforts have been made on assessing wildlife numbers in these areas (Gardner *et al.,* 2007; Stoner *et al.*, 2007b). There is some evidence that overall habitat degradation is lower in Tanzania's PAs than outside (Pelkey *et al*., 2000; Beale *et al.*, 2013), but effective protection of forests within protected areas is certainly mixed (Pfeifer *et al.*, 2012). While the IUCN guidelines advocate a rule of thumb law enforcement effort of one ranger/scout for every 10–50 sq. km (David *et al.*, 2016), the mean effort available for FPAs and LPAs within the study area is one scout/ranger for every 143 and 346 sq. km respectively indicating minimal enforcement in both categories (Nahonyo, 2005). Here, we use time series satellite datasets to investigate the status of land-cover in the various land use designations in the study areaover the past four decades. More specifically, we assess the spatial extent of deforestation in both FPAs and LPAs during that period, establish which of the two PA categories is effective in halting habitat change during that period and quantify available potential habitat for connectivity between the two ecosystems.

MATERIALS AND METHODS

Study area

The study area covers about 109,050 km² and lies between latitude 6015’59.38” to 8010’23.78” S and longitude 30045’13.29” to 35028’34.44” E. It comprises Katavi-Rukwa ecosystem in the west, a contingent of Game Reserves (hence forth “GRs”), GCAs and OAs in the central part as well as Ruaha-Rungwa ecosystem in the East (Figure 1). About 45,961 km² of this area is designated as FPAs (2 NPs, 7 GRs), 34,196 km² designated as LPAs (8 GCAs and 8 OAs) here in also referred to in our analysis as Region of Interest (ROI). A further 28,893 km² of land within the study area was considered as unclassified land and hence excluded from the analysis and include stowns and highly populated hamlets north and south of Katavi National Park, east of Muhesi Game Reserve and south of Lunda -Nkwambi GCA (Figure 1).

Data collection

Our analysis employed Landsat Multispectral Scanner (MSS), Landsat Thematic Mapper

(TM) and Landsat Enhanced Thematic Mapper (ETM+) for 1972, 1990 and 2015 respectively. The study area contained an intersection of 12 Landsat footprints (path/row 168/064, 169/064, 170/064, 171/064, 171/065, 170/065, 169/065, 168/065, 171/066, 170/066, 169/066 (Annexes 1-3). Cloud free Landsat images were downloaded from USGS website in single band GEOTIFF format pre-processed for atmospheric correction, geometric correction and noise-removal. The TM sensor has seven spectral bands (Boettingeret al., 2008; Brink & Eva, 2009) and is primarily designed to detect reflected radiation from the Earth's surface in the visible and near-infrared (IR) wavelengths (Shalaby & Tateishi 2007).

We obtained land-use data from the Tanzania Wildlife Research Institute (TAWIRI), a local government organ responsible for providing scientific information for promoting the development, improvement and protection of the wildlife industry. The dataset includedboundaries of NPs, GRs, GCAs, and OAsand road networks.

Image pre-processing

We used a combination of ENVI version 5.1 (Exelis Visual Information Solutions, Boulder, Colorado, USA) and ArcMap module of the ArcGIS 10x software for image preparation and processing. The first step involved geo-referencing imagesusing known locationstaken across the study area to reduce registration error (Jensen, 1996). We then applied image enhancement tool in ArcMap to improve visual interpretability by increasing the apparent distinction between different image features (Bradley & Mustard, 2005; Shalaby & Tateishi 2007). We further normalised each band stretching from 0 to 255 to improve visibility of different bodies with similar tones. To improve interpretability, we coloured composited individual image bandsto generate Colour Composites. For analysis we used bands 2, 3, and 4 for Landsat TM and ETM+ images and bands 6, 5 and 4 for Landsat MSS images.

Image processing

We first performed unsupervised classification using an Iterative Self-Organizing Data Analysis Technique Algorithm (ISODATA) which has been shown to perform better because of the statistical power it employs when classifying an unknown pixel (Shalaby & Tateishi, 2007; Brink & Eva, 2009). We set our preliminary classification result to yield a maximum of 30 spectral classes for historical (1972, 1990) and current (2015) maps (Ball & Hall, 1965). To obtain hybrid land cover maps, we visually interpreted and assigned the relevant landcover classes (from unsupervised classification) with the help of fielddata,Google earth images, expert knowledge and the recent countrywide landcover map developed by the National Forest Resources Monitoring and Assessment (NAFORMA) project (NAFORMA, 2015). Landcover classes for the final maps included Closed woodland, Open woodland, Bushland, Settlement/Cultivation, Wetland and Water. Description of theses land cover classes are provided in Table 1.

Table 1: Description of different land covers classes of the study area

Land cover	Description
Closed woodland	Tree layer with crown cover >40%
Open woodland	Tree layer with crown cover $\geq$10% and $\leq$40%
Bushland	Mixed vegetation types including thicket, dense bushland, bushland with scattered cultivation and Open bushland
Settlement/Cultivation	Open and cultivated agricultural grasslands mixed with settlement, grassland, shrubland, and impervious surfaces
Wetland	Vegetated lands with a high water table and inundated vegetation
Bare/Open Areas	Land areas of exposed soil surface as influenced by human impacts and/or natural causes. It contains sparse vegetation with very low plant cover value as a result of overgrazing, woodcutting, etc.
Water	Areas covered with water most of the year, Lakes, ocean, river, etc.

Source: National Forestry Resources Monitoring and Assessment of Tanzania Field Manual (NAFORMA, 2010).

Accuracy assessment

We assessed accuracy (Landgrebe, 2003; Mather, 2004) using 254 random points chosen to represent different land cover classes across the study area collected in 2015. We determined both omission error/producer accuracy to measure how well our images have been classified, commission error/user's accuracy to determine reliability of a pixel class on the map and the category on the ground as well as Kappa (Hat) to measures of agreement between the classification and the reference data (Olofsson *et al*., 2014). Accuracy above 85% is considered within the acceptable range (Anderson *et al*., 1976; Lins & Kleckner, 1996) while Kappa statistic above 80% is considered strong (Jensen, 1996). To obtain overall accuracy, we divided the total number of correct pixels (diagonal) by the total number of pixels in the error matrix (Olofsson *et al*., 2014). We could not assess accuracies for historical land-cover maps due to the lack of historical reference points.

Detecting change

Change detection (Singh 1989; Coppin, 2004) involved identifying pixels that were previously natural habitat in 1972 but later changed to field crops and settlements in 2015. To do this, we carried out a pixel-based raster analysis in three phases namely between 1972 and 1990, 1990 and 2015 as well as the overall change between 1972 and 2015. The analysis generated three different change tables as per the above phases and subsequently merged and used to calculate respective changes.

RESULTS

Land-cover classification and accuracy assessment

Overall accuracy assessment and Kappa coefficients for the 2015 final land-cover map (Figure 2) are 89% and 87% respectively (Table 2). User's and producer's accuracies for individual land-cover classes are high suggesting correct assignment of individual classes during classification (Table 2).

Table 2: Classification error matrix based on ground truth data collected in the study area

	Reference data					
Classification data	Closed Woodland	Open Woodland	Bushland	Crop fields	Wetland	Water
User accuracy						
Closed woodland	39	1	0	0	0	0
98						
Open woodland	11	49	6	2	2	0
70						
Bushland	0	0	43	2	2	0
91						
Crop fields	0	0	0	46	0	0
100						
Wetland	0	0	1	0	15	0
94						
Water	0	0	0	0	0	35
100						
Producer Accuracy	**78**	**98**	**86**	**92**	**79**	**100**
Overall Accuracy	89					
Kappa statistics	87					

Note: Percentage of pixels classified is shown by class with kappa statistic and producer, user and overall accuracy.

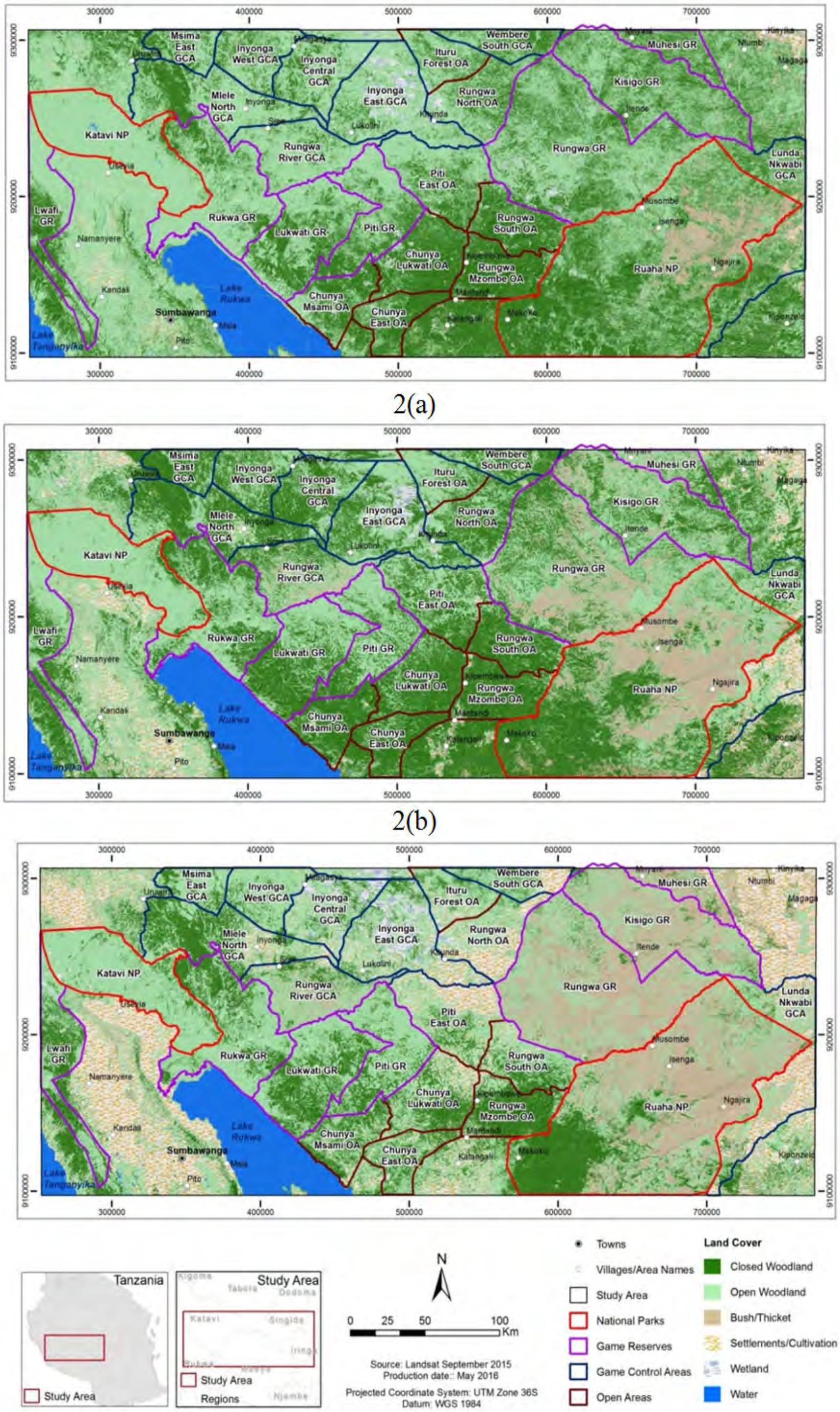

Fig. 2. Land cover maps showing trends in habitat decline over years. 2 (a) Land cover in 1972 indicating that closed and open woodlands combined comprised a large proportion of the study area then. 2(b) Land cover map in 1990 indicating dominance of closed and open woodlands combined still comprised a large proportion of the study area. 2(c) Landcover map in 2015 indicating massive reduction in natural habitat. National Parks (Katavi and Ruaha) and Game Reserves (Rukwa, Lukwati, Piti, Rungwa, Kisigo and Muhesi) landscapes remained intact whilst Game Controlled Areas (GCAs and OAs) are significantly reduced to crop fields and settlements at the expense of natural habitat.

Status of land use/cover in and around LPAs (GCAs and OAs)

In 1972, areas between and surrounding the two ecosystems entirely comprised of natural habitats (Fig. 2a). Two decades later (between 1972 & 1990), these areas combined lost an estimated 1,060 km^2 of natural habitat to crop fields and settlements equivalent to 3% of natural habitat available in 1972 (Figure 2b). Much of the loss occurred between 1990 and 2015 where an estimated 4,900 km^2 of natural habitat was lost to crop fields and settlements which is equivalent to 6% of habitat available in 1972 (Fig. 3). Piti East and Rungwa South Open Areas which provide the potential habitat for connectivity between the two ecosystems lost a combined total area of about 1,200 km^2 of natural habitat to crop field and settlement between 1972 and 2015, with 89% of the loss occurring between 1990 and 2015 (Fig. 2c). Overall, habitat within and around LPAs have lost an estimated 5,984 km^2 (equivalent to 17.5%) of natural habitat to agricultural and settlement activities between 1972 and 2015 (Figure 3).

Status of land use/cover in FPAs (NPs and GRs)

Apart from subtle habitat losses detected in Muhesi and Rukwa Game Reserves, FPAs remained relatively intact throughout suggesting their land use designation has been effective in preventing habitat loss over long term (Fig. 3).

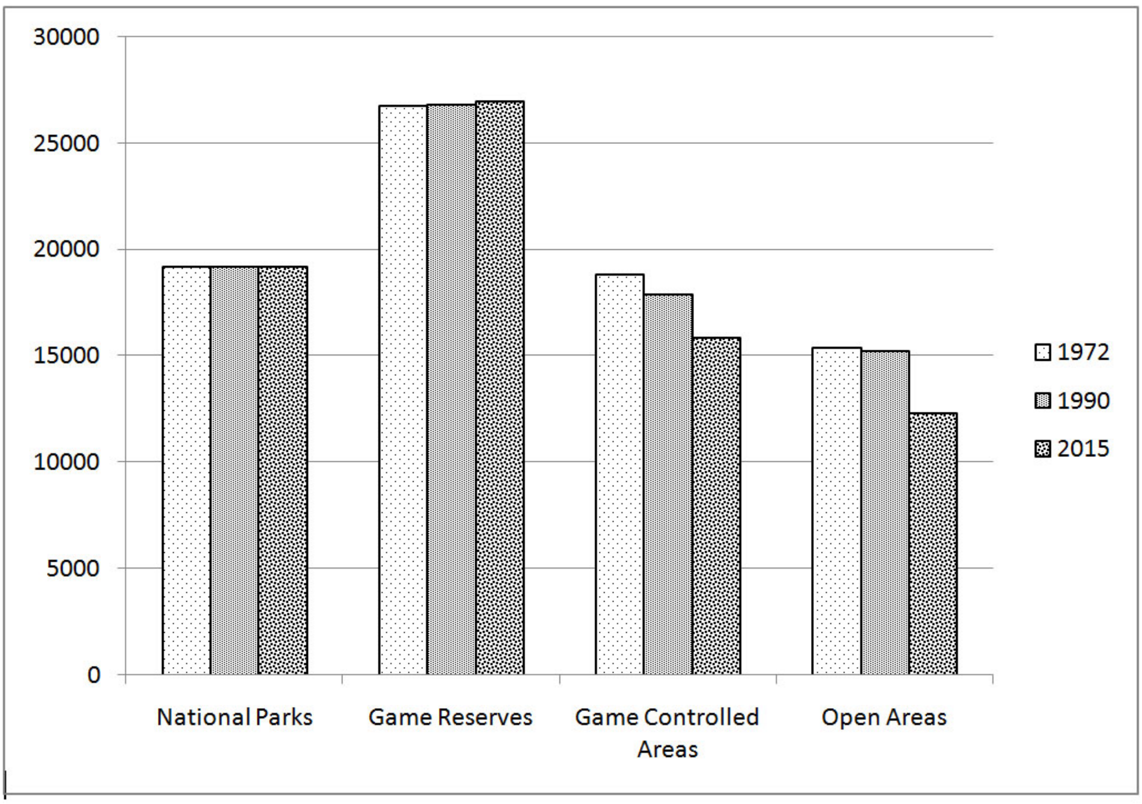

Fig. 3. Overall habitat reduction (in km^2) in all four land use categories in the study area between 1972 and 2015. Habitat in National Parks and Game Reserves remain unchanged throughout suggesting the effectiveness of full protection.

DISCUSSION

Our analysis revealed that FPAs are effective at preventing total habitat loss in the study area, despite minimal investment in enforcement (Figure 3). Our results support previous findings conducted across the country which found an increase in vegetative cover in FPAs with LPAs suffering worse habitat degradation than areas with no legal protection (Pelkey *et al*., 2000). In addition, a study conducted across tropical countries that found 83% of PAs were effective at preventing land clearance (Bruner *et al*., 2001). While habitat within FPAs in the study area remained relatively intact with minimum investment, we note that this may overlook losses of highly valuable tree species such as African Blackwood (*Dalbergia melanoxylon*) and sealing-wax tree (*Pterocarpus angolensis*) (Caro *et al*., 2005) that may be selectively removed from within the miombo woodlands without total habitat loss. Our observation on the ground experience affirms this is happening in this part of Tanzania on large scale (Caro *et al.,* 2005). Extensive selective cutting of high valued tree species is not only widespread in all PA categories within the study area but also documented elsewhere within FPAs in central Tanzania where increasing rarity has compelled wood carvers to shift to less preferred Miombo species (*Brachystegia speciformis*) (Madulu, 2001). Similarly, there is evidence of widespread elephant poaching within FPAs across the sub Saharan Africa (Brennan & Kalsi, 2015), and in the Ruaha ecosystem in particular (TAWIRI, 2014; Chase *et al*., 2016), suggesting a distinction between successful habitat preservation and successful protection of high value species within that habitat again.

In contrast to FPAs, LPAs in ROI have experienced rapid habitat loss in the study area, with 17.5% transformed to agricultural activities between 1972 and 2015. Most LPAs within the study area and elsewhere in the country have limited resources for enforcement. LPAs such as Piti East and Rungwa South OAs rely on help from adjacent FPAs namely Piti and Rungwa Game Reserves respectively (pers. observ.). Much of the conversion in these areas can be attributed to weak enforcement coupled with increased human population densities attracted by nearby resources (Wittemyer *et al*., 2008; c.f. Serengeti NP: Metzger *et al*., 2010) and the poor ability of the land to sustain agriculture (Campbell, 1996; Malmer, 2007). In many cases, human conversion of natural habitats occurs most rapidly in the locations important to biodiversity because humans tend to concentrate in rich biodiversity locations (Hansen *et al*., 2012), often resulting in elevated levels of exploitation in these locations (Brashares *et al.*, 2001; Parks & Harcourt, 2002).

Miombo woodland generally occurs on low fertility soils which limits intensive agriculture, causing people to adopt destructive and unstable forms of agriculture and pastoralism activities (MacKinnon *et al.,* 1986; Malmer, 2007), often at the expense of natural habitat (Mwalyosi, 1991). This leads to shifting agriculture not only because fertility declines fast on newly-cleared fields, but also because invasion of weeds makes it labour intensive to re-cultivate and hence,they are often abandoned (MacKinnon *et al*., 1986). Such losses outside FPAs are a concern because wide-ranging species such as African elephants (*Loxodonta africana*) require vast areas that may not be provided by FPAs to guarantee long-term survival (McNeely & Scherr, 2003; Zuidema & Sayer 2003; Laurance *et al*. 2006; Michalski *et al*. 2007; Vandermeer & Perfecto 2007; Harvey *et al.* 2008; Hansen *et al.*, 2012). For example, African elephants spend a substantial amount of their time outside protected areas in Northern Tanzania (e.g. Tarangire National Park: Galanti *et al*., 2006) and elsewhere (Douglas-Hamilton *et al.*, 2005). Escalating habitat loss through expanding agricultural and pastoralist activities within LPAs and around FPAs across the country threatens the few remaining corridors (Caro *et al*., 2009; Jones *et al.*, 2009) and could potentially reduce genetic exchange (Rodrigues *et al*., 2004a; Newmark, 2008; Graham *et al*., 2009; Craigie *et al.*, 2010).

Currently, Tanzania has about 17% of her land area devoted to wildlife conservation in PAs where no human settlement is allowed and further 18% of its surface area to PAs where wildlife co-exist with humans (MNRT, 2007). This network of PAs is coming under intense public scrutiny, with the government seeking to ensure development and conservation are adequately balanced across the country (Rutasitara *et al*., 2010) and there is little desire to increase the proportion of land in FPAs (Kideghesho *et al*., 2007). Indeed, the recent Southern Agricultural Growth Corridor of Tanzania (SAGCOT) initiative 2011 is explicitly targeting intensification of agriculture within the coastal plains and the valleys of Kilombero and Ruaha, on the hills and valleys of the Southern Highlands and the Usangu flats, including many areas of high biodiversity value (Milder *et al*., 2013; Wuyts & Kilama, 2015).

Out of an estimated 26,090 km^2 of natural habitat that remains in ROI today, about 3,380 km^2 within Piti East and Rungwa provides potential habitat for connectivity between Rukwa-Katavi and Ruaha-Rungwa ecosystems. Both Piti East and Rungwa permit utilization through hunting of big game. However, Piti East OA was recently abandoned by hunting companies due to increasing number of livestock in the vicinity coupled with a substantial decline in large mammal populations, rendering the block currently uneconomical. The lack of interested hunting companies to invest in Piti East OA makes it vulnerable to greater habitat loss. Adequately protecting these two areas could secure connectivity between the two largest populations of African elephants of Katavi-Rukwa and Ruaha-Rungwa ecosystems in south-western Tanzania (Jones *et al.*, 2009).

RECOMMENDATIONS

Protecting the remaining habitat connecting Ruaha-Rungwa & Katavi-Rukwa ecosystems is a high priority. Increasing enforcement in LPAs within the study area and the country at large could help reduce the on-going conversions given the current political situation encouraging WMA establishment than new FPAs, although in practice it achieves the same result if well implemented. Additionally, the land here is marginal at best for agriculture, so the development of a WMA offers a solution that could allow greater local community buy-in. The area will need restoration before it can be economically self-sustaining and this needs investment, with some initial funds expected from Wildlife Conservation Society (WCS), Reducing Emissions from Deforestation and Degradation (REDD) programs offers other funding sources. Our analysis suggests that without increased protection, this corridor will be lost in the next few years.

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IMPACT OF LAND USE CHANGES ON THE HEALTH OF LAKES BABATI AND BURUNGE, NORTHERN TANZANIA

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ABSTRACT

The study assessed the impact of anthropogenic activities and land use changes on the health of Lakes Babati and Burunge. Six villages adjacent to the two lakes were involved in the study. Data were collected using questionnaire surveys, key informant interviews, field observation, and Remote Sensing. Findings indicate that encroachment; overfishing, soil erosion and siltation were the major anthropogenic activities impacting the health of the two lakes. From 2000 to 2017, the average proportion of land use changes adjacent to Lake Babati and cultivation increased by (44.8%, 12.6%), (28%, 18.1%) and (2%, 11.7%) while grazing decreased by 8%, 38.4% and 11% for Majengo, Singe and Bagara villages respectively. For lake Burunge the average land use change for cultivated land was 46.3% during the same period. Grazing decreased by 29.1% 24.2 % and 11.6%. for Sangaiwe, Vilima Vitatu and Mwada villages respectively The study recommends that local communities and stakeholders involvement in Lakes management and establishment of adequate buffer zones.

Keywords: Anthropogenic activities, Geographical Information System, Land use, Remote Sensing

INTRODUCTION

Lakes sustainability is an aspect that requires researchers and practitioners to consider a wide range of different disciplines (Odada *et al.*, 2006). The management of Lakes is facing numerous challenges nowadays, some of them related to natural (Gopal & Wetzel, 2005) and many others to anthropogenic causes (Mc Cartney et al., 2004; Safari *et al*., 2012). Climate change in particular will have serious consequences for Lake environments, while human's increasing demands will require an integrated approach to ensure long-term Lake management, considering not only the watershed area but also the different socio-economic and ecological aspects (ITCL, 2009; Yanda and Madulu, 2005).

The word sustainability has gained popularity locally, nationally and worldwide in recent years. The motive behind is exponential human population growth (Hongoa & Makundi, 2014) and climate change which have simultaneously induced high environmental stress to natural resources (Kaswamila, 2006). There is sufficient body of literature to suggest that terrestrial resources can be utilized to combat rampart poverty without impairing their sustainability (Nonga, 2012). However, only few have a focus on sustainability of aquatic resources (Hoverman & Johnson, 2012; IUCN, 2012). Either, there has been little attention on the impacts of anthropogenic activities on Lakes Babati and Burunge resources (Nindi &

Itani, 2008; Nindi, 2010). Assessment of the impacts of land use changes around these Lakes is needed in order to develop appropriate and timely conservation actions (Misana *et al.*, 2006).

Lake Babati biotic and abiotic resources forms a lifeline of Babati township communities and beyond by acting as a source of income through primarily fishing activities and fish mongering (Kahurananga, 1992). Lake Babati has about 200 indigenous fish species which are thought to be facing possible extinction (BTC, 2011). Responsible human activities for these threats include but not limited to horticulture, beekeeping, brick making and construction of infrastructure but also for watering animals (Kahurananga, 1992). However, the Lake has great potential of being a tourist attraction for Babati due to its beautiful surroundings and breathtaking scenery (BTC, 2011; URT, 2013). Lake Burunge on the other hand is one of the soda Lakes of the Rift Valley of Northern Tanzania. Lake Burunge is believed to be a feeding ground for flamingos and it is a part of Tarangire and Lake Manyara National Park's ecosystems. Human activities carried adjacent to the Lake include livestock grazing, farming, fishing, water collection, building materials collection and bird trapping. The Lake is now under threat from over-utilization, inadequate management, lack of basic information and public awareness of the importance to man and wildlife (Hassan, 1993; BTC, 2012). The intensification of agriculture around the Lake coupled with application of fertilizers and pesticides lead to the siltation and eutrophication (Kaswamila, 2006; Yanda & Madulu, 2005).

Previous studies indicate that the water level at Lake Babati has decreased from 8 - 6 metres in 1970's (Gerdén *et al*., 1992; Kahurananga, 1992) to 4 - 3 metres in 2013 as a result of siltation due to anthropogenic activities (Katonge & Kaswamila, 2013) and the estimated annual catch in the Lake has also been dropping steadily since 1970 due to decreased water levels, anthropogenic activities (BTC, 2011; Katonge & Kaswamila, 2013). For example, the number diminished from an average of 300 tons per year in 1970 equivalent to 2500 fish catch a day (Gerdén *et al*., 1992; Kahurananga, 1992) to an average of 60 tons per year equivalent to 500 fish catch a day in 2013 (Katonge & Kaswamila, 2013).

The Babati district government has been taking several measures to mitigate the problem of decrease in fishery resources, reduced growth, pollution and degradation of Lakes such as prohibiting fishing for some months, prohibiting people from grazing close to the Lake, illegal fishing using poison as well as washing clothes and cars (BTC, 2011; Yanda & Madulu, 2005). Despite these efforts by the government and other stakeholders, water quality, fishery resources stocks and water levels have continued to decline threatening the existence of the lakes (Camilla, 2011; Lyding, 2009; Yanda & Madulu, 2005). The aim of this study was to examine anthropogenic activities and land use changes in Lake Babati and Lake Burunge. Specifically, the negative impacts associated with anthropogenic activities and land uses types adjacent to Lake Babati and Lake Burunge were assessed.

MATERIALS AND METHODS

Site visits were conducted in villages adjacent to each Lake to identify the extent/ level of land degradation and pollution, human encroachment and siltation. Where necessary Photographs were taken. This method assisted the researcher to compare the existing land uses with those provided by the key informant and documentary review to obtain reliable data of the study area.

Questionnaires were used to collect information from the local residents and fishermen. The questionnaire had open and closed-ended questions because the open-ended questions gave the respondents an opportunity to express their insights in detail, while closed ended questions helped to save the time to both respondents and interviewer. This involved three stages; Training of field assistants, questionnaire pre-testing and administration.

Two field assistants involved in collecting data were trained. They were picked one from each village with the help of VEO of the particular village. Local assistants were preferred so as to avoid research biasness as they are not having personal interest in the study and they were able to interpret some concepts in vernacular language for respondents who do not understand Swahili language. These assistants were trained for 1 day prior the actual data collection process. Training was mainly on how to administer questionnaires, probing questions and recording the responses

Questionnaire were pretested by researcher and two research assistants in order to check the questionnaire wording, sequencing and layout. Pre-testing also helped the researcher to know whether questions are clear and answerable. After pretesting the questions which were found to be unclear were revised ready for use.

The research team administered questionnaires to the sampled population. On average the interviewers spent 2 days in each village for logistic arrangements and administration of questionnaires. After each day the principal researcher reviewed the questionnaires to check if they were filled properly.

The interviews with key informants were conducted using a checklist guide. Themes covered were the prevailing economic activities adjacent to lakes, types and number of catches of fishery resources, water pollution, conservation challenges, environmental awareness and land use changes prevailing in the study area. The key informants included 6 officials based on subject specialization; Fisheries, Environmental Officer, Land officer from each lake. Data on land use types were collected from land officers.

Land use changes were determined using GIS and remote sense methods. The Images of 2000 and 2017 was geo-referenced using ERDAS IMAGINE 9.1 Software with reference to a topographical map of scale 1:50000 of the study site to cover only the area of interest. Three rectified images were reduced to the size of the study site by using subset command in ERDAS image software. The image coordinates were transformed into map coordinates as per 36 Universal Transverse Mercator (UTM) zone, projected to UTM.

The Demographic characteristics of the respondents adjacent to lake Babati (Table 1) indicated that majority (64.5%) of the respondents were males. However, in Singe village, females were relatively higher (53.3%) compared to the rest. The reasons for more males could not be established, however, this could have happened by chance.

Lake Babati study revealed various anthropogenic activities in the area included encroachment, overgrazing, deforestation, cultivation, fishing, livestock keeping, brick making and beekeeping. Furthermore, we also noted siltation from rivers, discharge of organic debris from human settlements around the Lake and run-offs from agricultural fields.

Table 1: Demographic characteristics of households villages adjacent to Lake Babati

Village	Population	Village size (Ha)	Sample size (n)	Sex (%)		Age of respondents (%)				Size of Household (%)			Education level (%)		
				Male	Female	18-29	30-39	40-49	> 50	1-3	4-6	> 6	Informal	Secondar	>Second
Majengo	4,802	380	20	66.7	33.3	13	53	27	7	35	42	23	73	7	20
Singe	3,240	274	20	46.7	53.3	46	20	14	20	29	33	39	66	26	8
Bagara	3,013	268	20	80	20	25	40	26.6	8.4	35	44	21	60	20	20
Average	**3,685**	**307**	**20**	**64.5**	**35.5**	**28**	**37.7**	**22.5**	**11.8**	**33**	**40**	**27**	**66**	**18**	**16**

Source: Village Government Office. July, 2017. n = Sample size

Regarding Lake sustainability, numerous anthropogenic activities were cited to threaten the Lake. Respondents in Majengo largely revealed encroachment as a major challenge. This result could be due to the fact that, communities have cultivated within the buffer zone leading to loss of pastures for hippo. Thus, degradation of riparian zones affects the surface and ground water resources and the aquatic fauna and flora; and the terrestrial ecosystem.

Overfishing was the generic impact asserted by almost half of the respondents in each village. This could be due to presence of many fishermen in the study area. According to BTC (2017), the fish catch in 2000 and 2017 was 70 tons and 23 tons respectively. Fishermen have increased from 166 to 337 between 2000 and 2017 (ibid). Through key informant interviews, the study revealed presence of 380 fishermen fishing in Lake Babati with 150 fishing boats and fish catch of 5 tons. Although the number of fishermen has been increasing every year, fish catch has been decreasing. The decrease is said to be due to lack of modern fishing equipments, weather and dryness caused by environmental degradation and depletion of fish because of using inappropriate fishing gears.

Singe and Bagara respondents on the other hand ranked soil erosion and siltation as the leading challenge with the former resulting into large gullies in the buffer zones. The ecological implication of such erosion could be the deposition of eroded sediments in the Lake hence damaging the spawning grounds of fish. Siltation process suggests the ongoing decrease of Lake Babati depth as it is documented by BTC (2017) that, it has changed from 8 to 5 m between 2000 and 2011 and from 5 to 4 m between 2011 and 2017.

Results indicated that areas adjacent to Lake Babati have gone through tremendous changes in land use and land cover for the period from 2000 to 2017. Land Uses in Majengo Village has changed such that both residential area and cultivated area have increased by 4.8% and 3.2% respectively while grazing land has decreased by 8% between 2000 and 2017 (Fig 1 & 2). The decreased grazing land could be attributed by the rapid population increase which demands more areas for cultivation and settlements.

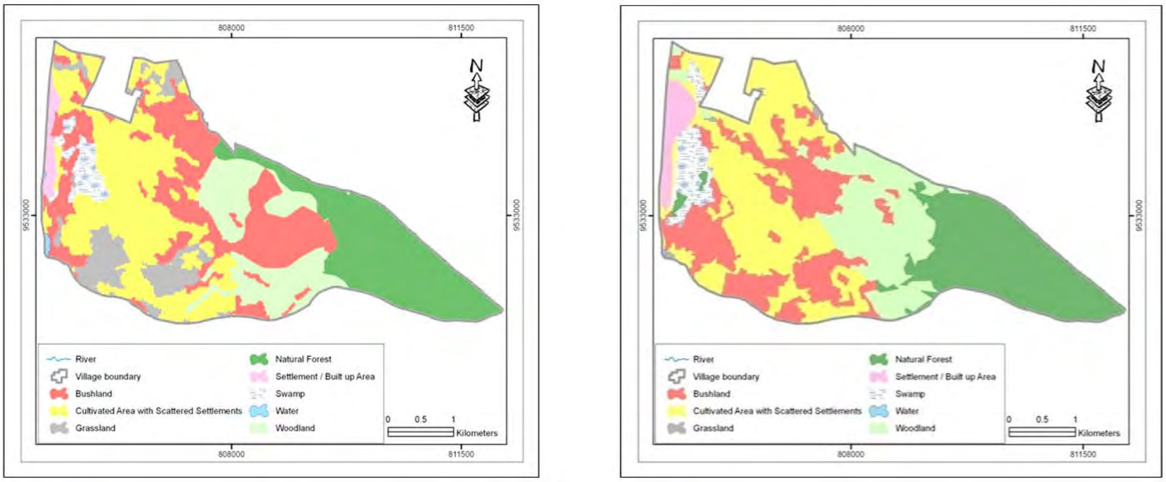

Fig. 1. Majengo land cover maps 1(a) in the year 2000 and 1(b) in the year 2017

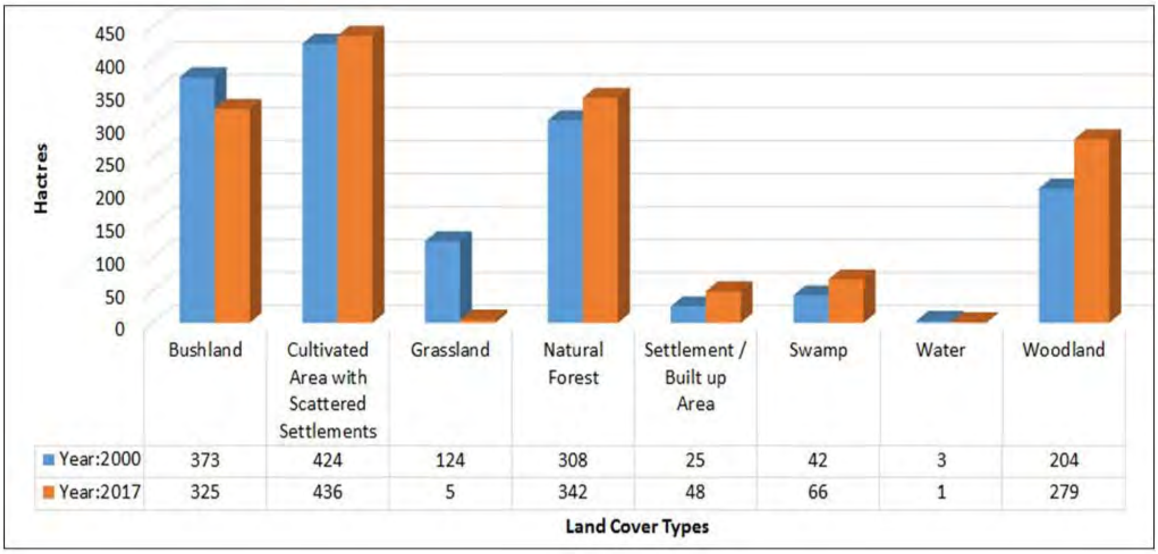

Fig. 2. Majengo Village chart land cover chat changes

The implication of land use changes in this village has resulted into unauthorized grazing of livestock in the buffer zone of Lake Babati. The study noted improper management of the Lake banks as they were seriously trampled by livestock leading into soil erosion and siltation to the lake. This village is relatively closer to the Lake about less than 0.5 kilometres hence the insufficient riparian zone remained was severely used for grazing leaving the land bare with no grasses.

Singe village located 1.2 km from the lake shows an increase in both residence and cultivated areas by 7.9% and 4.1% respectively between 2000 and 2017 (See Fig 3 & 4). It has one seasonal river valley that attracts more farmers to invest in vegetables and Banana plantation a situation that could be the reason for more immigrants to this village looking for residence and cultivation land. Grazing area on the other hand has decreased by 12% over those years. Presence of seasonal river valley and clay-loam soil that favors brick making could be the reason for most pastoralists turned on this activity instead of livestock keeping as the grazing land was limited.

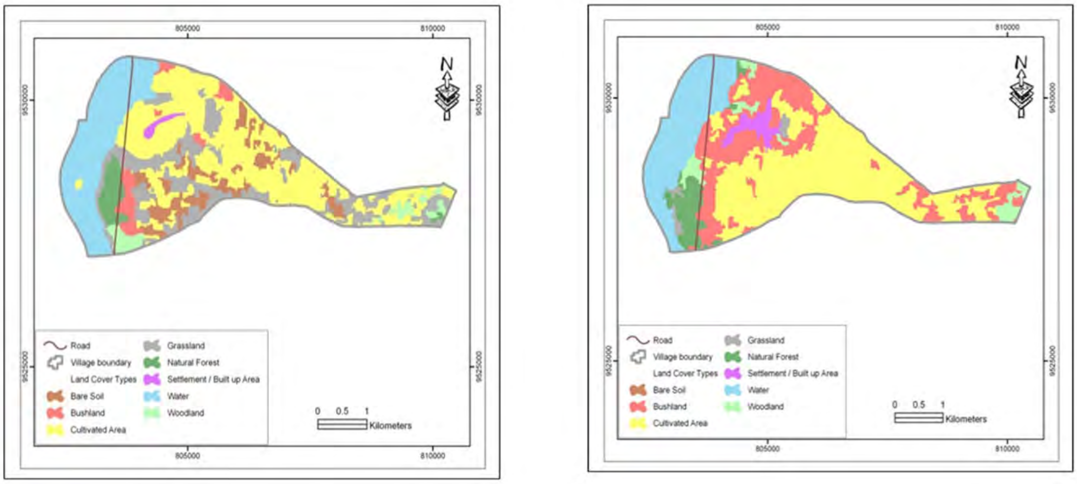

Fig. 3. Singe village land cover maps 3(a) in the year 2000 and 3(b) in the year 2017

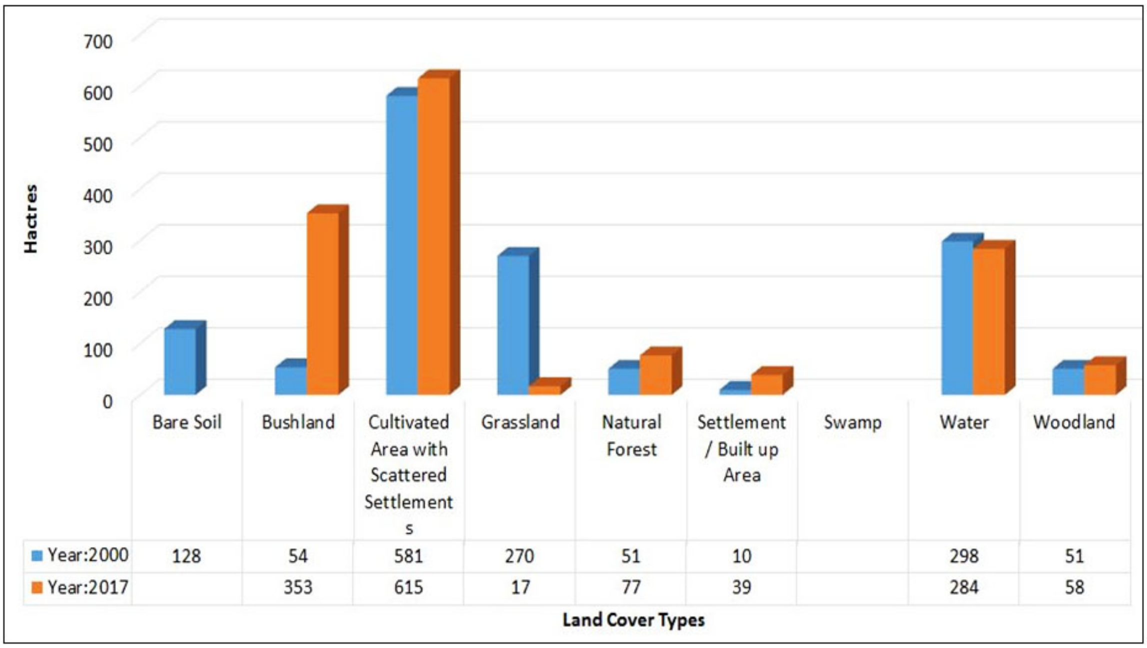

Fig. 4. Singe village land cover changes chart (2000 - 2017)

Unlike other study villages, Bagara had an increase in grazing area by 4% between 2000 and 2017 (See Fig. 5 & 6). The study through FGD revealed shifting in Lake water towards south since 2008. The probable reason for water shifting could be due to siltation in the lake as it has been documented in the work of Katonge and Kaswamila (2013) that, flooding of Lake Babati in 2004 was exacerbated by decrease in water depth from 8 m to 6 m between 2004 and 2007. Pastoralists in this village take advantage of this area left by water for grazing their livestock.

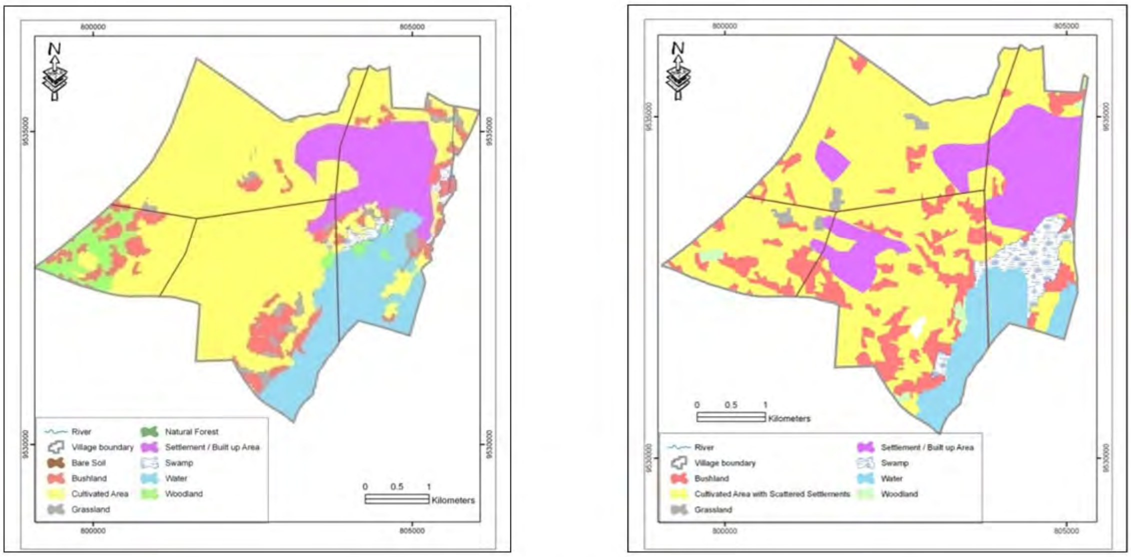

Fig. 5. Baraga land cover maps 5(a) in the year 2000 and 5(b) in the year 2017

The Demographic characteristics of the respondents adjacent to Lake Burunge (Table 2) interviewed in this study indicate that (63%) of the respondents were males. However, in Vilima vitatu males were relatively higher (75%) compared to the rest. The reasons for more males could not be established, however, this could have happened by chance.

Table 2: Demographic characteristics of households adjacent to lake Burunge

Village	Population	Village size (km²)	Sample size (n)	Sex (%)		Age of respondents (%)				Size of Household (%)			Education level (%)		
				Male	Female	18-29	30-39	40-49	> 50	1-3 people	4-6 people	> 6 people	Informal and Primary	Secondary	>Secondary
Mwada	3,602	59	25	58	42	33	30	28	9	30	41	29	53	16	31
Sangaiwe	4,540	92	30	56	44	37	38	13	12	49	23	29	55	27	18
Vilima Vitatu	5,813	198	35	75	25	30	47	16	7	44	35	21	65	15	20
Average	**2,955**	**116.3**	**30**	**63**	**37**	**33.3**	**38.3**	**19**	**9.3**	**41**	**33**	**26**	**57.6**	**19.4**	**23**

Source: Village Government Office. July, 2017. n = Sample size

On average, majority (41%) of the households in the study villages were having household size of about 1- 3. On education, the level of literacy, in most villages seems to be low as most (57.6%) of the respondents had primary and/or informal education. This implies that, education level in the study area is still low which could suggest low knowledge among communities in addressing issues related to land use changes and sustainable Lake management.

In assessing the grazing activities in the tall and the short grasslands around the Lake, the study revealed that 85% of those who keep domesticated animals (80% reported that, they used mostly the west and the south parts of the Lake shore for grazing activities). While the 15% of them were utilizing other areas for their livestock grazing such as Lake Manyara shore.

In assessing this aspect, a considerable number (91.7%) of people interviewed reported that the water points, the springs, swamps, walls and Tarangire river estuaries are the major sources for their daily water collection. Lake Burunge also provides other benefits to the people who use to collect materials mainly grasses and poles from its shore for building purposes. 55% of people interviewed reported that the tall grassland and the woodland in the western side of the Lake are important sources for their building materials. The rest 45% said that, they depend on other areas for collecting building materials without specification. Because of its proximity to settlements Lake Burunge provides other important values to the surrounding inhabitants.

Results from this study indicated that areas adjacent to Lake Burunge have gone through tremendous changes in land use and land cover for the period from 2000 to 2017. The analysis of Landsat images through ArcGIS 10 software generated the maps of woodland, bushland/ scattered tree or open woodland, grassland, cultivated land, water bodies and wetland cover classes. Land use changes in the study areas were assessed between 2000 and 2017 and results are presented (Figs 7-12).

Data from Land cover suggests that land use in Mwada Village has changed such that cultivated area have increased by 30% while grazing land has decreased by 3% between 2000 and 2017 (See Fig. 6). The decreased grazing land could be attributed by the rapid population increase which demands more areas for cultivation and settlements.

Sangaiwe village located 1.3 km from the Lake also shows an increase in cultivated areas by 53% between 2000 and 2017 (See Fig. 7). Grazing area on the other hand has decreased by 12% over those years.

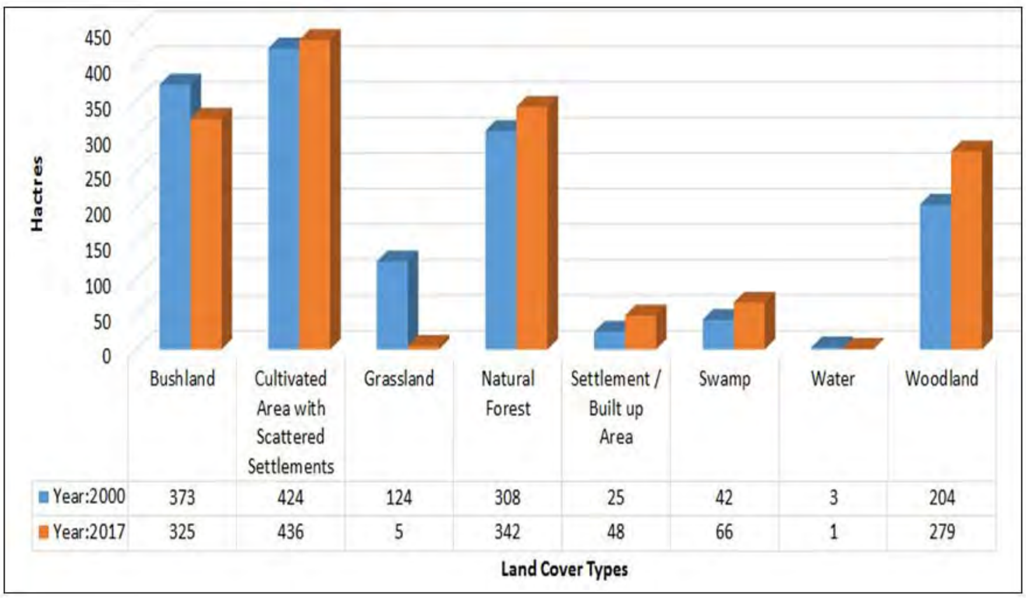

Fig. 6. Mwada village land cover change chart (2000 - 2017)

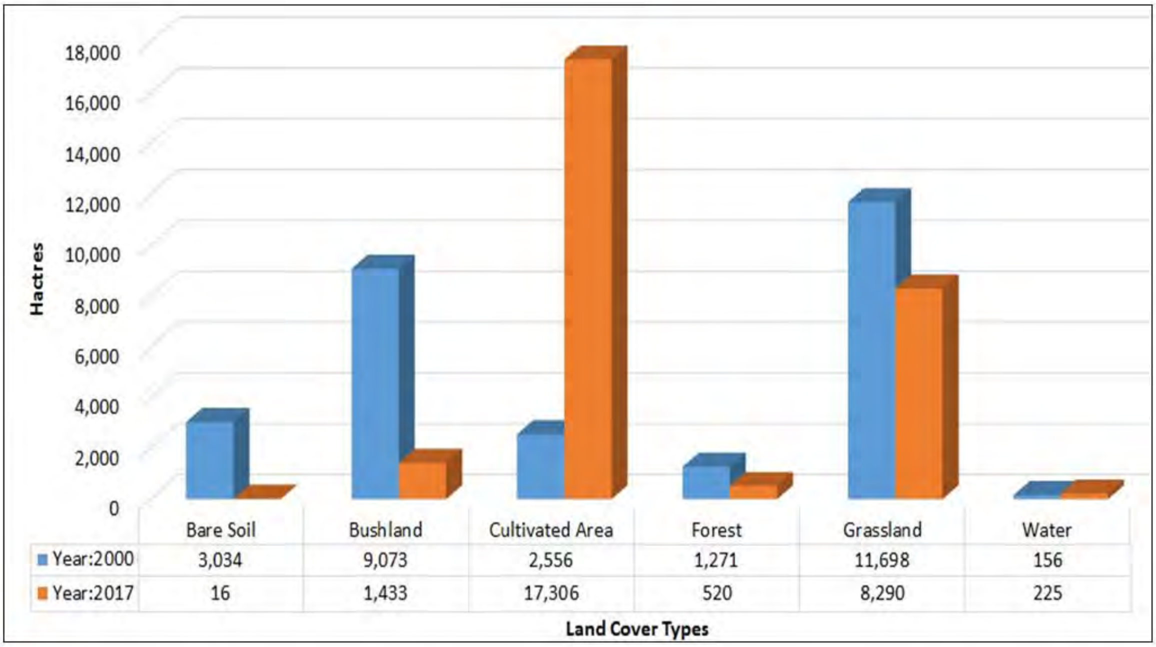

Fig. 7. Sangaiwe village land cover change chart (2000 – 2017)

Data from land cover suggests that land uses in Vilima vitatu village has changed such that cultivated area have increased by 36% while grazing land has decreased by 12% between 2000 and 2017 (Fig. 8). The decreased grazing land could be attributed by the rapid population increase which demands more areas for cultivation and settlements. The probable reason for such increase in human population could be due to immigrants from different areas (BDC, 2017).

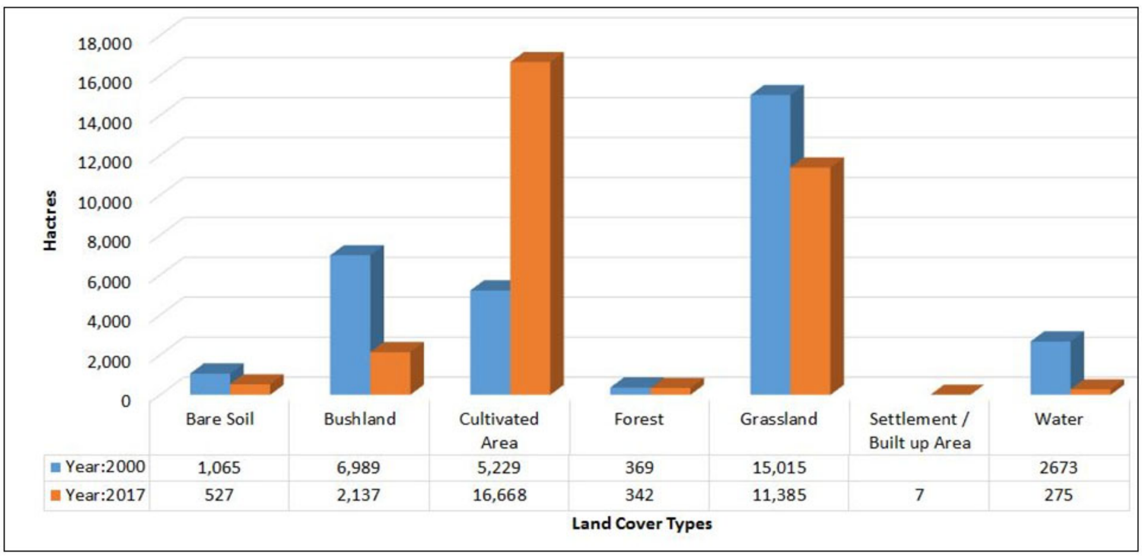

Fig. 8. Vilima vitatu village land cover chart (2000-2017)

DISCUSSION

In the present study it was seen that the areas around the Lakes were under threats of being completely degraded. Activities that pose threats to the integrity of Lake Babati and Lake Burunge as a whole include habitat change due to agriculture, grazing, housing, mining and quarrying; cutting of aquatic and other vegetation for fuel, housing and commercial activities; Improper fishing practices; siltation due to deposition of erosion materials that reduce the depth of the Lakes; pollution by domestic sewage, industrial effluent, and agrochemicals; siltation caused by poor agricultural methods and eutrophication leading to oxygen depletion.

The decreased grazing land in Majengo Village could be attributed by the rapid population increase which demands more areas for cultivation and settlements. The probable reason for such increase in human population could be due to the upgrading of Babati Town into Manyara regional headquarter leading to more immigrants from different areas. Therefore, District authority has been converting many parts of the district land into new settlement plots (BTC, 2017). On the other side of this approach, could be the reason for decrease in grazing land as District Town Planner asserted that pastoralists in the urban area have already informed to reduce their herd size due to shortage of land. A study by Kaswamila (2006) suggested that, unless the Government adopted the Participatory land use plan in planning both rural and urban areas, impacts associated with land use changes will continue to affect biodiversity and livelihood due to development exacerbated by globalization.

The increased settlements and economic activities mainly cultivation and brick making adjacent to the Lake Babati could undermine the enhanced conservation efforts of the riparian forests through over harvesting of fuel wood for brick making and domestic consumption. The unsustainable cultivation practices with no terraces and a great number of gullies through brick making along the Lake shores have made this village prone to soil erosion and siltation. The study revealed use of excessive amount of soil in brick making causing soil degradation. Kiln process used at present in this village is highly inefficient hence brick makers use huge amount of fuel resulting to deforestation of riparian forests. Besides these, the waste along with water flows back in the Lake Babati, increasing the total solids causing siltation. Therefore, for effective management of the Lake Babati, the Brick making activity should be reallocated distant to the Lake buffer zone.

A sign of overgrazing was justified by a considerable number of domesticated animals observed and counted in the small size pasture on Lake Burunge shore with an average width range of 100 to 250 m. Generally, the problem of overgrazing is always associated with the communal grazing system practiced by the pastoralists in which low productivity forces each family to keep many Cattle purposely for sustenance. The low productivity is related to the low fertility in its saline soils (Hoverman & Johnson, 2012).

In this area rain water runs off from the surrounding high grounds to the lowlands particularly valleys such as Lake Burunge. This results to the formation of seasonal flood plains in these areas which are usually utilized by large number of domesticated animals. Also, the drastic reduction of natural vegetation due to human settlement, cultivation and wood utilization contributes to the diminishing of grazing lands in the area. During this study it was observed that the western shore of the lake from northern part extending southwards to the Sangaiwe village was occupied by crop cultivation and settlement. This clearly indicated that pastoralists (the Barabaig) have less or lack alternative grazing lands around the Lake. There were small scale farms and daily movements to the grazing and watering areas indicated the significance of the Lake shore and watering points. Consequently, their grazing activity is restricted mainly to the western side of the Lake, while the eastern side is mostly used by wildlife. The use of the western shore for livestock and eastern shore for wildlife has advantage in the sense that there is a sequential use of the Lake shore by livestock and wildlife. The former is using the Lake shore mostly during the wet season while the later during the dry season.

As for crop farming, 67% of people utilized the land extending from the north to the south along the western lake shore. The others 33% used to farm on other areas away from the shore such as Lake Manyara plains and the areas adjacent to the Great North Road shows the reasons that encourage people to farm around the shore. Distribution of human settlements and cultivated lands for 2000 and 2017 around Lake Burunge are shown. They clearly indicate the differences in the pattern of settlements distribution and land under crop production between the two time periods.

The low altitude (950 m.a.s.l) and low average rainfall (500 mm) in semi-arid lowlands, zone V compared to other agro-ecological zones in Babati District resulted in very limited crop production in the area (Hoverman & Johnson., 2012). This can be justified by the lack of farming lands with better conditions (e.g. fertile soils with moisture content) as one of the major reasons forced the villagers to concentrate their agricultural activities von the lake shores.

On the other hand, the relatively good farming conditions around the Lake (perhaps due to the fertile soils with moisture content) have been the main impetus for human immigration in the most villages such as Mwada and Sangaiwe. The other factors responsible to human influx into the area includes its proximity to the great north road serving the Manyara, Arusha and Kilimanjaro regions as well as the present social economical development such as employment, business and social services. Additionally, the low rainfall experienced in 1991, 1992 and 1993 forced many local people to concentrate their activities in areas with more moisture content and higher productivity particularly on the Lake Burunge shore. Nowadays the lowland plains of Babati district where Lake Burunge and Lake Manyara are located are highly populated probably because of the favorable conditions for settlements and crop farming. Hongoa & Makundi (2014) reported that human population growth rates are highest in the lowlands below the Rift Valley mainly for the same reasons. He commented that, crop and stock threaten the viability of households and villages in general.

Lake Burunge also provides other benefits to the people who use to collect materials mainly grasses and poles from its shore for building purposes. 55% of people interviewed reported that the tall grassland and the woodland in the western side of the lake are important sources for their building materials. The rest 45% depend on other areas for collecting building materials without specification. Because of its proximity to settlements Lake Burunge provides other important values to the surrounding inhabitants. The grasses, the sedges and the woody vegetation in its shore are major building materials in the area. If not, almost all houses seen around are constructed from natural building materials especially the roofing parts. Many activities were observed in the lake shore and the woodland extension such as vegetation cutting and charcoal burning respectively.

The study concludes that, the noted land use changes between 2000 and 2017 are mainly due to unsustainable human practices and has induced much pressure on Lakes and its resources. The main weaknesses undermining the ongoing conservation strategies of Lake Babati and Burunge were water pollution poor community participation and lack of proper land use plan that should allocate appropriate area for each land use category. Therefore, appropriate measures including involvement of relevant stakeholders' particularly local communities in Lake management should be taken when designing polices to increase the long-term sustainability of fishing activities in the Lakes.

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ASSESSMENT OF HUMAN DISTURBANCES ON FLIGHT DISTANCE IN BIRDS AT MOROGORO MUNICIPAL AND SURROUNDING AREAS, TANZANIA

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ABSTRACT

Flight initiation distance (FID), the distance at which an organism begins to flee from an approaching predator or threat, is associated with prey escape decision-making processes with benefit and cost trade-offs to remaining in a patch. Factors that may affect FID can be altered by human-stimulated predation risk, although the magnitude of response may depend on human exposure towards the animal. Through this study, I investigated the effect of human disturbance on the bird's initial behavior, how FID vary between the selected species of two species commonly found in cities including the House sparrow (*Passer domesticus*) and Indian house crows (*Corvuss plendens*) in three sites corresponding to three levels of human exposure. I also investigated other probable factors that might influence flight behavior in birds. Our results showed that birds found in the rural zones were very shy to human disturbances and therefore showed high flight initiation distances compared to those found in the urban and peri-urban areas. Then I concluded that flight initiation distance varies among different species of birds depending on the extent of human disturbances on a particular area.

Keywords: Birds, disturbance, human, flight initiation distance

INTRODUCTION

The effect of human disturbance on animals is frequently measured in terms of changes in behavior in response to human presence. The magnitude of these changes in behavior is then often used as a measure of the relative susceptibility of species to disturbance, for example the study by Gill *et al*.(2001) showed that the species which show strong avoidance of human presence are often considered to be in greater need of protection from disturbance than those which do not. Previous studies revealed that the assessment of weather disturbance affect and how severe that effect is, currently rely on proximate measures of the effects of disturbance usually the behavioral response of the species in question to human presence (Stalmaster & Newman, 1978; Burger, 1981; Tuite *et al* . 1984). Birds display many behaviors that indicate their level of tolerance or sensitivity to humans and their activities these include scanning behavior (head-turning), agitation behavior (bird raises its head, tenses its body, turns to look at the humans, flaps its wings, takes a few steps) and escape behavior either bird walks, jumps, runs, flies, swims, or dives away (Brown, 1990; Anthony *et al*. 1995; Delaney *et al*. 1999; Ferna´ndezJuricic *et al.* 2001; Swarthout & Steidl, 2001).

Depending on the species and the circumstance, some of these exposures to human activities may result in adverse effects to the birds. What matters is not if a bird shows alert behavior or moves away, but whether and how the behavior affects the birds or the species as a whole (Gill *et al*. 2001; Gill, 2007). Adverse effects from human disturbance include reductions in feeding rates (Belanger & B ´ edard, 1989; Burger 1994; Merkel et al. 2009; Velando & Munilla, 2011), reproductive success and productivity (Beale & Monaghan 2004; McClung *et al*., 2004; Medeiros *et al*., 2007; Zuberogoitia *et al*., 2008), and survival (Anderson & Keith, 1980). Apart from human disturbances there are many factors that influence FID in bird species, one of them is the group size (Glover *et al*. 2011). Given that more eyes and ears are available to detect the predators (the many-eyes hypothesis: Pulliam, 1973), larger groups of animals may flee at greater distances because of the increased vigilance level and prior detection of the stimuli (Aastrup, 2000). Another factor that influence FID among animals' species is sociality. Sociality have many trait more social species may be generally more vigilant because they have monitor both conspecific and predators and this wariness might make species more responsive in approaching human(Cahan *et al*., 2002). Also the life history of urban and rural populations can differ substantially, for example different food availability, different types of predation, higher population density can modify behavior of birds (Ditchkoffet al., 2006). Moreover, individual with compromised visibility increase vigilance (Leger *et al*., 1983; Arnez & Leger, 1997; Boinski *et al*., 2003,Blumstein *et al*., 2004b) this because dense vegetation reduce detection to threats.

This study therefore firstly investigated the effect of human disturbance on the bird's initial behavior, and examine how it varies between the selected species of two birds species commonly found in cities including the House sparrow (Passer domesticus) and Indian house crows (*Corvus splendens*) in three sites corresponding to three levels of human exposure. Secondly, I investigated the other probable factors that might influence flight behavior in birds in the Morogoro municipal.

MATERIAL AND METHODS

Study area

Morogoro is located at about 200 km west of Dar es Salaam city between latitudes 5°00' and 7°40' S of the equator and longitudes 37°10' and 38°33'E of Greenwich Meridian. The municipality has a population of approximately 600,000 people (Mayor- Morogoro municipality pers. com, 2012) in an area of more than 65 km^2 at the foot of the Uluguru Mountains. The annual rainfall ranges from 600 to 1,000 mm with bimodal pattern characterized by short rains from November to January and long rains during March to May. The mean monthly temperature varies between 21° and 27° C. The predominant vegetation cover is miombo woodland (Rija *et al*., 2014b). The wildlife of the study area included birds such as House sparrow (*Passer domesticus*), Indian house crow (*Corvus splendens*) water birds such as marabou stocks around Mindu dam, vervet monkey, small mammals such as Giant pouched rat, hedgehog, bushbaby (Galagos), reptiles such as green snake, cobra, monitor lizard and giant plated lizard.

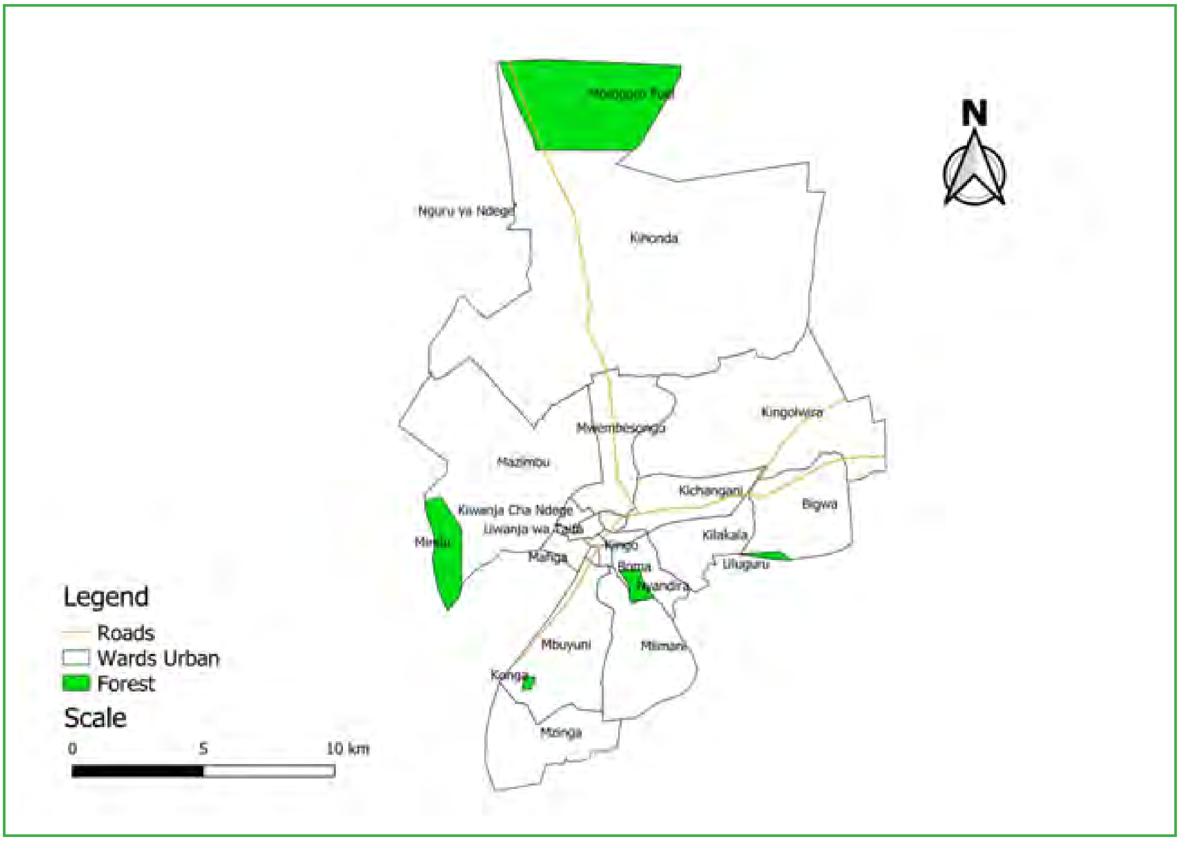

Fig. 1. Map of the study area

Data collection

The study involved three sites basing on the development of the municipal and these sites were categorized as core urban zone, peri-urban zone and the rural zone. The core urban zone involved areas around Morogoro town , SUA main campus areas starting from the main get and rural zone involved areas around Magadu village near Uluguru mountain up to mzinga area.

Observation method was used in data collection whereby road transect of about 3 km was established in each site during data collection. Observations were done in the morning at 07:00-10:30 am and after noon starting from 01:00-03:30 pm. Data collection involved recording of human activities likely to affect behavior in birds such as the extent of pedestrian movement, motor vehicle movement and noises and see how they have influence on the behavior of birds particularly the selected bird species. Also, behavior change when bird first approached by a human were recorded, this included activities like scanning behavior (head-turning), agitation behavior (bird raises its head, tenses its body, turns to look at the humans, flaps its wings, takes a few steps) and escape behavior either bird walked, jumped, ran, flee, swims, or dives away. Also FID were collected for both species in different study site. FID measured as the distance between the observer where the bird is feeding prior to fleeing and the observer identifying the location of the observer at the instant the bird ran away.

Data analysis

Data analysis was done using the Microsoft excel of 2007 to show the influence of human disturbances on the flight initiation distance on birds particularly on House sparrow and Indian house crow across the rural-urban gradient of Morogoro municipal in Tanzania. Also, it was used to show the relationship that exist between the number of birds and flight initiation distance for the data collected both in rural zone and urban zone this is because flight initiation distance vary with the group size of the birds, the large group size the smaller the FID also it vary depending on the level of human disturbances that range between low, medium and high. The frequencies of each bird species at particular time were also analyzed by using Microsoft excel of 2007 to see how many times birds appeared at particular location and time. The frequencies of birds' activity versus time were also compared.

RESULTS

Bird frequencies

I recorded 387 observations of birds for both the house sparrow and Indian house crow across the rural urban gradient in Morogoro municipal. Of this, the total number observations of house sparrow was 277 for both rural zone and urban zone and the number of observations for the Indian house crow was 110 both in rural and urban zone. Also, it was found that the proportion of house sparrow is higher in the rural zone due to the reason that the area was not much disturbed and had plenty of the places for feeding and even resting while the proportion of Indian house crow was higher in urban zone even though area had many human disturbances such as pedestrians and motor vehicle movement and noises due to availabilities of may wastes and rubbishes sites where they use for feeding. See the results in table 1 & 2 showing the frequencies of birds, house sparrow and Indian house crow at morning and afternoon time for both rural and urban zones.

Table 1. Bird species frequency in rural zone at different observation time

Species	Morning	Afternoon	Total
HS	119	123	242
IHC	18	13	31

Table 2. Bird species frequency in urban zone at different observation time

Species	Morning	Afternoon	Total
HS	22	13	35
IHC	41	38	31

Sources of disturbances to birds

According to the observation made across the rural-urban gradient, pedestrians and motor vehicle movement were the main source of disturbance to the birds particularly to the house sparrow and Indian house crow. Even though those birds appeared to be tolerant to these disturbances, but they remain the main causes of disturbance which influence their flight initiation distance (FID). The proportion of these disturbances differ across the rural–urban gradient. The disturbances were higher in urban zone due to presence of high number of vehicles and pedestrian movement as result few number of these birds inhabited these areas as compared to the rural zone where the areas are less disturbed providing plenty of spaces for foraging, roosting and habitat.

Behavior of birds before and after approach

During observation across the rural–urban gradient in Morogoro municipal the birds before approached mostly they were performing different behavioral activities. Most the birds activities recorded were just resting, feeding, dust bathing and others social singing but this depended on the time where the observation was made. All those activities shown by birds before being approached were recorded and put on Microsoft excel for statistical analyses to see the frequency of each activities per time (Table 3). After being approached they reacted differently. The birds from rural zone were very shy and their FID were higher dueto high predator avoidance. In contrast, in urban zone FID for both species were smaller and these were associated with the presence of high human disturbances such as frequent pedestrians, cyclists and motor vehicle movements and therefore predator avoidance to them is very low. Therefore FID is different between rural areas and urban areas because the number of human disturbance recorded were quite different, urban areas had very high human disturbances.

Table 3. Birds activities frequency before approached by man at different time

Activity	Freq (%)	Mor.	Aft.
Dust bathing	8	2	0
Feeding	50	7	5
Resting	29	2	7
Singing	12	1	2

Most birds were found feeding more during the morning (Fig.1), while others were just resting in different parts such as on vegetation, buildings and other structures. The remaining few were found doing dust bathing and social singing especially during the morning hours mostly done by house sparrows

After being approached they also responded differently. As some showed scanning behavior, jump, flaps wings and flee away but the responses were different among birds. Birds found in rural zone were very shy and showed greater predator avoidance than those that were found in urban zone as they were very tolerance to human disturbances.

Other factors influencing FID

Based on the observations made, the group size of the individual bird species had influence on the flight initiation distance in birds. It was observed that the larger the group size of birds the smaller the flight initiation distance (FID) whereby the fewer the number of birds the larger the flight initiation distance of birds in rural zone (Fig. 3). While, the urban zone the number of individual birds versus FID varied (Fig. 4).

More it was observed that birds in rural zone showed higher FID compared to the urban zone because probably birds in the rural zone were shy and had greater predator avoidance. This is because they rarely experience high human disturbances compared to those in urban zone.

DISCUSSION

Abundances of House sparrow and Indian house crow across rural - urban gradient

It was found that the number of birds species particularly house sparrow was higher in the rural and peri-urban areas. This was because there was a little human disturbances compared to the urban areas where the landscape is more urbanized, that led to the decline of birds' population. The Indian house crow tend to be highly distributed in urban areas around Morogoro municipal because of the availability of areas suitable for them such as many dumping sites. Also, because the Indian house crow tend to eat wastes hence they are inhabited in urban areas despite the presence of many disturbances like pedestrian movement and vehicle movement. Resource quality and abundance, and predation risk, should both influence habitat choice by birds, because selection would be expected to favor a choice that optimizes energy and nutrient input and promotes survival (Frid & Dill 2002; Cooper & Frederick 2007). As natural predators and humans appear to share some common 'threatening' properties for many birds, avoidance of human disturbance might also be expected to influence habitat selection, particularly when it is long-lasting and intense. (Verbeek 1982; Grubb & King 1991; Carrete *et al.* 2002).

Behavior of birds before and after approach

It was observed that during and before birds were approached, they exhibited different behaviors to human disturbances. Before approached by human, birds behave differently as resting on the trees, feeding, social singing and some were doing dust bathing. While, after approached most of birds (the house sparrow and Indian house crow) flee away from the human exposures and some showed scanning behavior while others showed agitation behavior then flee away from human disturbances. The level of birds' response to human disturbance differ to birds across rural-urban gradient. Birds observed in rural areas were very shy and tended to flee far away from human disturbances. This was because the areas were not very much disturbed by human activities, whereas birds in urban areas especially the Indian house crows were very tolerant to human disturbances. When compared with rural birds, urban birds had shorter alert distances (AD), flight initiation distances (FID), and delay escape more ,Despite the fact that the starting distance (SD) used to approach individual birds was much smaller in urban sites, urban birds took longer to be alerted by an approaching human.(Samia & Blumstein, 2014). This was because they were frequently encountered with these disturbances, therefore during observation they were not shy to human exposures unless approached to the nearest distance. However, the Indian house crow mostly found in urban areas and less in the rural areas like in Magadu village and all the way to mzinga areas.

Variation in flight initiation distance (FID)

It was found that FID was influenced by many other factors. One of them was the level of human exposures, and it decreased along the high, medium, low gradient of human population. FID was found to be higher in the rural areas than in the urban areas. This was because birds in the rural areas experienced little human disturbances and the level of human disturbances was quite low compared to the urban ones. During our observations, the House sparrow as well as Indian house crow once approached they flee immediately after detecting the approaching human while the FID was observed to be low in urban areas. This was because of several factors that were noted, one of them being highest degree of tolerance to human disturbances of these birds' species. This was because those birds they co¬-existed with human, therefore they frequently encounter with human disturbances such as pedestrians movement and noises as well as motor vehicles movement.

Also apart from human disturbances there are other probable factors influencing flight initiation distance to birds such factor include the flock size. FID was found to be lower when birds were found to associate in larger number unless you approach them to the closer distance. But when they were in few in numbers, they were found to be very shy and once approached by a human they flee immediately.

CONCLUSION AND RECOMMENDATIONS

The house sparrow and the Indian house crow are the most bird's species that tolerate to the human disturbance compared to the other types of bird's this is because they usually co-exist with human . Therefore apart from the human disturbances to have influence on the FID in birds particularly on the house sparrow and the Indian house crow there are other impacts on birds that are associated with the human disturbances for example frequent human disturbances interferes with the birds feeding behavior (foraging) and the reproductive success to birds .

It's important for the authorities that are concerned with the management and protection of the protected areas such as National parks, game reserves to plan properly for visitor's activities in a manner that it does not bring impacts to the birds. Also they are supposed to balance the population of visitors as well as number of vehicles entering the protected areas so as to reduce disturbance pressures to the birds . Moreover the infrastructures especially roads should be well and appropriate planned so that movements of visitors from one place to another does not impose excess disturbances to the birds behavior.

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POPULATION DISTRIBUTION, THREATS AND CONSERVATION AWARENESS OF AFRICAN CLAWLESS OTTER IN MTERA DAM ECOSYSTEM, TANZANIA

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ABSTRACT

African clawless otter is among 7 species of otter found in the world which are regarded as threatened due to habitat loss, illegal hunting and retaliatory killing and range contraction. Conservation of the clawless otters is of particular concern especially in areas increasingly contested due to human activities man-made dam used as otter habitats such as Mtera dam in central Tanzania. Despite the increasing pressure on the otter habitats, its food base and illegal hunting, basic information about the species ecology and awareness among local people are scarce, risking increasing threats to the species. This study aimed at assessing distribution of otter species, existing threats and the knowledge and awareness of otter otters in the Mtera Dam and terrestrial ecosystem. A systematic transects survey for species distribution and questionnaire survey and interviews were used to understand conservation awareness in the local communities. Land cover change over two decades was also quantified using available remote sensing tools. The result shows that fisherman where more knowledgeable about otter species. However, their attitudes toward otter existence differed significantly in terms of use values, attractiveness and harmfulness of otter. The study also shows that there is habitat deterioration due to increase in agriculture and livestock keeping in the study area. Likewise, increase in fisherman population over time, has caused the distribution range of otter species to constrict and hence population decrease. Generally, use of illegal fishing gears, habitat deterioration due to increased human activities was the major threats facing African clawless otters in the study area. Management of fishing activities along the dam is recommended for thriving population of Otter.

Keywords: Awareness, Clawless otter, distribution, threats, and Mtera dam

INTRODUCTION

Otter are regarded as key indicators of the health of aquatic and wetland ecosystems. Clawless otters are semi-aquatic and require permanent and continuous water ways (Estes *et al*., 2010). Otter are normally found in lakes, swamps, rivers, and sometimes in mountain streams at higher elevations (Smith & Chadwik, 2010). Otter also live in dens, which are found near water sources. Otters are likely to be present throughout most of its historic range even though, in reduced numbers due to habitat degradation, conflicts, polluted waterways and increased human animosity towards this species e.g. use as a meat source (Somers, 2001). Currently, otters are declining in numbers in many places due to changes in their environment and human interference (De Luca *et al*., 2018). Some of the reasons include the increased use of nylon fishing nets, in which otter get tangled in and die (Vlastimil & vlaclavick, 2010). Fish-farmers and fur-trappers are also playing a major part in the decline of the African clawless otter (Somers, 2001). Otters also face a lot of conflicts with fishermen who view them as a problem because otter take fish and damage fishermen nets, which are expensive especially for poor families relying heavily on fishing as a means of their livelihoods. Another threat to otter is related to traditional beliefs whereby local people use for medicinal and food sources (Vlastimil & vlaclavick, 2010: De Luca *et al*., 2018). Conflicts arising from interactions between people and wild animals influence the future survival of many wild species including otter (Nyahongo & Røskaft, 2011). Lack of awareness and species knowledge by the local residents can threaten species survival through persecution, retaliatory killing and hunting (Drew, 2005). Generally, the main cause for conflict appears to be the local people's perception of damage caused by otter's species to nylons nets, together with a perception of prey depletion (fish, crabs and prawns) (Fonseca & Marmontel, 2012).

According to International union for conservation of nature (2014) out of the 13 species of otter worldwide, 12 are threatened and endangered. The population of clawless otter is continually decreasing with very little data on the presence and status of these species in their usual habitat (Jacques *et al*., 2016). Studies show that this decline is due to habitat loss driven by both legal and illegal fishing activities (Kruuk & Goudswaard, 1990), as well as unsustainable agriculture (Rowe-Rowe, 1992). Like other species, otter utilize habitat even those found outsides protected area. Hence, across species' distributional range, populations are likely to be exposed to various threat levels under differing management regimes. The main objective was to investigate the distribution of otter in unprotected habitats. Information on the distribution and factors that threaten the population growth of clawless otter outside protected area are also assessed in the study.

MATERIALS AND METHODS

Study area

Mtera Dam is the largest hydroelectric dam in Tanzania. The dam is located at the border between Iringa and Dodoma regions. The dam is found within 7°08'10.3"S 35°59'12.6"E. It measures 660 square kilometers (250 sq. mi) at full capacity. The dam is 56 kilometers (35 mi) long, and 15 kilometers (9.3 mi) wide, and is feed by the Great Ruaha River and the Kizigo River (Fig.1). Mtera dam was constructed from 1975 to 1979 for the purpose of regulating water level at the downstream of the Ruaha installed Kidatu Hydro-electric Dam. The area is generally semi-arid with an average rainfall of about 400 mm per year, most of which fall between November and early April. The temperature ranges between 20^{o}C and 30^{o}C. Moreover, the dam supports a lot of spectacular wildlife species including hippos, crocodile, fish, birds and many others including cape clawless otter. The area was estimated to have 3,088 human population in 2002 and increased to 10, 934 in 2012 (URT, 2011; NBS, 2013).

Methods

A cross-sectional survey design was used in this study (Hulley *et al.*, 2013). A questionnaire survey, participatory rural appraisal technique (PRA) and GIS technique were used to collect data on awareness, threats and occurrence of otter species from the local fisherman. Purposively six villages (fishing camps) were studied based on their proximity, accessibility and population. Simple random sampling was employed to obtain a sample population from the updated fisherman register book from the village executive officer. A total of 150 fishermen from 5 villages (Mtera, chibwegere, chamsisiri,makuka and makatapola) around Mtera Dam were interviewed. PRA was employed in order to get comprehensive information on what fisherman think are the major threats facing otter and their proposed solution (Pretty, 1995; Rietbergen-mccracken *et al*., 1998). Study respondents were selected based on their gender, age, position in the society, education level and availability in the discussion during the study period. For PRA, the respondents were grouped in small groups of ten people. During the lPRA, all information were written down by the researchers and for each category (challenges and solutions) fisherman's were given 2 pairs of beans seeds and asked to vote for the most preferred point in that category (Abeyasekera, 2001). The votes were counted and scoring was done so as to have a proper ranking from each respondent. The researchers explained the meanings of the values obtained and agreed together with the fisherman on the scores and ranks produced thereafter. Boat transect of 10 km and ground walking transect (1-3 km) were also employed to assess the distribution, habitat and threats facing the species (Rowe-rowe, 1992). In order to assess the occurrence of species, the study followed recommendations by Rowe-rowe (1977). Otter distribution was recognized by recording the spraints whereby they were identified by size, diameter, shape and also categorized the sites as latrine' or 'non-latrine' depending on the scats found together (1 or more clustered within 50 cm^2). Spraint age was recorded as very fresh (1 day old), fresh (2-3 days old) or old (more than 3 days) as suggested by (De Luca *et al*., 2018). Also, camera traps (Reconyx, 500H remotely triggered) was used for 20 days (10 days in October and 10 days in December) to understand the distribution and threats facing the clawless otter in their recognized habitat. Lastly, habitat analysis was assessed using change detection model using Q-GIS from a period of over 30 years in 10 years apart.

DATA ANALYSIS

Quantitative data were analyzed using SPSS version 16 to produce the descriptive statistics on the awareness and threats variables and content analysis was used for qualitative data obtained during PRA. In this study, post classification comparison was used to quantify the extent of land cover changes over the 30 years period (1988, 2008, and 2018). The advantage of post classification comparison is that it bypasses the difficulties associated with the analysis of the images that are acquired at different times of the year, or by different sensors and results in high change detection accuracy (Li *et al*., 2008). PAST program was used to show the relationships between measured perceptions of the threats to the fisherman using Non-metric multidimensional scaling.

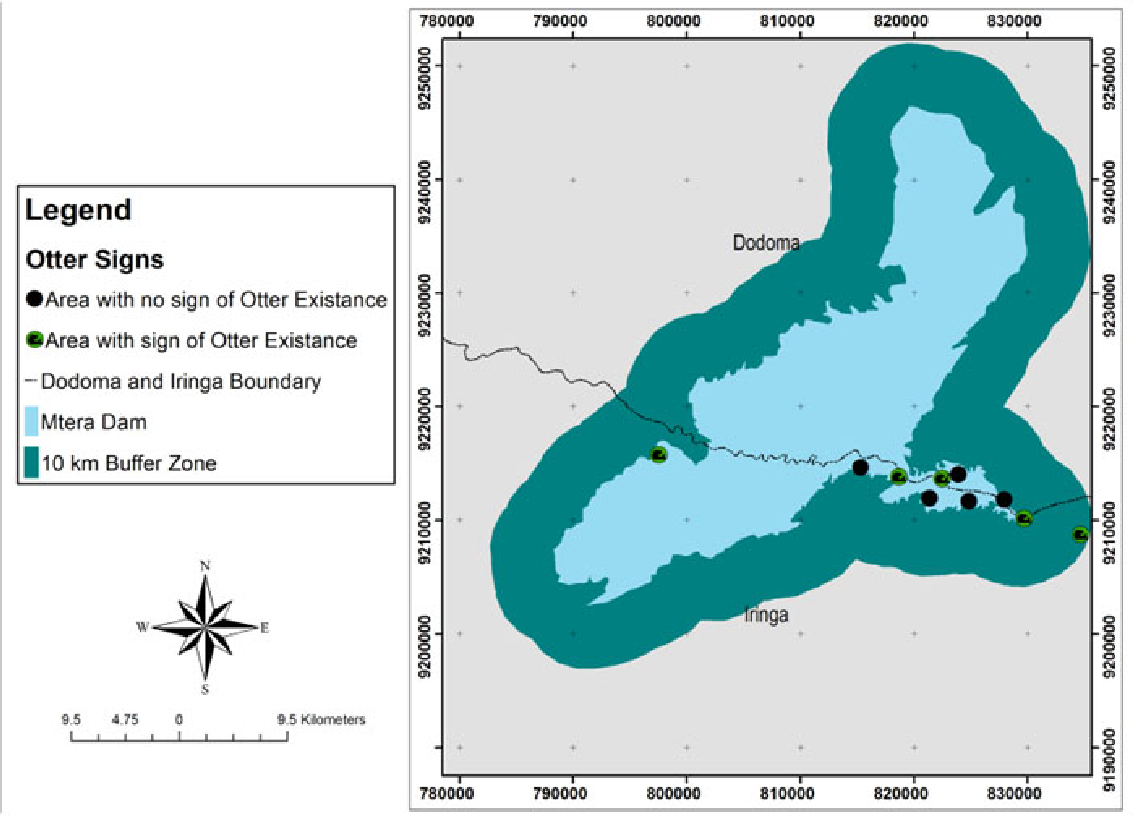

Figure 1: Distribution map of Otter in areas recommended by the fishermen during questionnaire survey.

RESULTS

Fishermen awareness, knowledge and attitude

Most of the respondents (87 % n = 150) of the respondents were aware of the presence of clawless otter in their areas by correctly identifying clawless otter in the shown picture while 13% couldn't identify the animal and were also not aware of it (Table 1). About 66% (n = 142) of the respondents said yes, they like otter while 30% didn't like the animal and remain 6% didn't know whether the do like the animal or not.

Reason for liking the animal

Majority of the fishermen (53.1%, n = 96) indicated that otter have no harm, 24% being otter behavior (braveness, sharpness and creepy), 11% says otter are attractive animals, 7% like the animal because they were the source of food and 2% says the do contribute to national income through tourism. Lastly was 1 % whom says otter are indicators of fish availability in the area (Table 1).

Reason for not liking the animal

Results also show that 45% (n = 40) of the respondents who don't like the otter perceived otter to have no any value to them, while 30% said they hate otter because they do eat their fish, 22.5% of the respondents didn't have any reason while 2.5% argued that otter destroy their fish nets.

Table 1: Fishermen awareness, knowledge and attitude

Question	Reason/answer	Frequency	Percent
Do you know this animal?(n=30)	Yes	130	86.7
	No	20	13.3
Do you like this animal? (n=142)	Yes	94	66.2
	No	42	29.6
	I don't know	6	4.2
If yes why do you like it? n=96	Attractive	11	11.5
	Brave/sharp/cryptic	24	25.0
	Food	7	7.3
	Has no any harm to human	51	53.1
	Indicators where there are many fish	1	1.0
	Contribute to national income	2	2.1
If no why don't you like the animal? (n=40)	Eating fish	12	30.0
	No any value	18	45.0
	Destructing fish nets	1	2.5
	I don't know them	9	22.5

Distribution of African Clawless otter

Otter distributions in Mtera Dam was assessed using a mixture of both social survey and ground transects. The use of ground transect was important in order to triangulate the information provided by fishermen from the questionnaires. Fishermen were asked to mention when and where do they normally see otter in Mtera and other areas (Fig 2). All the areas mentioned by fishermen that are in Mtera dam were assessed using ground transect. The assessment was carried out both during the day (to look for otter and signs of their presence) but also during the night (to look for active individuals). In each area,assessment was conducted in a ground transect (3 km long and 50 meters wide off shore) for about 24 man-hours per transect for 5 days during the night and 2 days in day time. The result shows that out of 11 different sites mentioned by fishermen only 5 sites had positive results during ground transect. Otter were seen or signs of their presence were observed. Distribution of otters as was suggested by fishermen and as was observed from the ground transect (Fig. 2). Whereby the black dot indicate that the area was recommended by the fishermen but have negative result during transect survey (no signs of otter or individual seen) while the circle with otter in the map are area with positive result in which researcher had find signs or individuals in the area during transect survey.

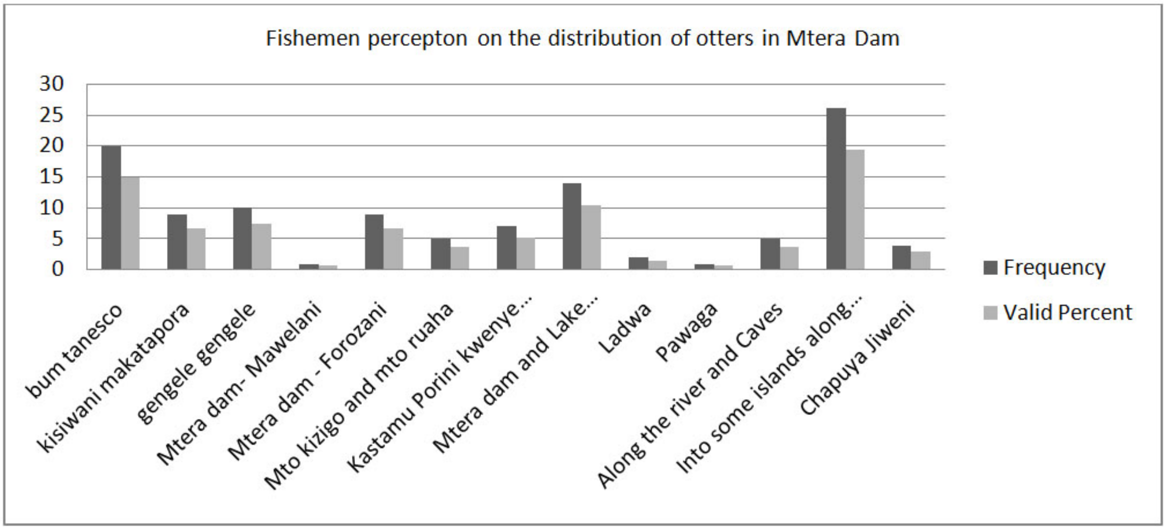

Fig. 2. Areas mention by fishermen where otter can be found in both Mtera and other areas

Threats

Results of the likert scale shows that (36.3 %,n = 140) of the fishermen strongly disagreed that water pollution causes decrease in the population of otter, while 35% agreed that high fishing activities have illegal fishing gears negatively affect the population of otter (Table 2). Furthermore, (31.7%, n = 140) strongly agreed that high human population around the dam also affects the otter population, while, 48.8% strongly disagreed that agriculture activities around the dam has negative effects on the population of otter (Table 2). 40.8% (n = 140) of fishermen strongly agreed that lack of awareness of otter and its conservation practices has contributed to the decrease of otter' population and 39.8% strongly disagreed that cultural uses of otter can result to a decrease in the population of otter (Table 2).

Also, in order to measure the extent of the fishermen opinion and their association, analysis of Non-metric Multidimensional scaling was employed. NMDs shows a clear relation between factors perceived to have no influence on the distribution of otter agriculture activities, water pollution and cultural uses to have no influence and other factors remain to have positive influence on threats to otter where as illegal fishing activities to have as a huge threats to the existence of otter in the dam (Fig. 3).

Table 2: Fishermen perceptions about the potential threats of Otter					
Potential threat	Percentage strongly disagree	Likely disagree	neutral	agree	strongly agree
Water pollution resulted to decrease of population of this animal?	36.3	14.5	15.3	16.1	17.7
High fishing activities has high impact on population?	12.0	13.6	14.4	35.2	24.8
Use of illegal fishing gears contributes more decrease of the animal?	10.3	8.7	11.9	31.0	38.1
High human population around the area resulted to decrease the population of the animal?	22.2	9.5	13.5	23.0	31.7
Agriculture activities contribute more decrease?	48.8	18.4	13.6	9.6	9.6
Lack of awareness of this animal result more decrease?	24.0	10.4	8.0	16.8	40.8
Cultural uses result more hunting of these animal?	39.8	13.0	18.7	12.2	16.3
Shoreline population has more serious impact?	25.0	10.5	10.5	28.2	25.8

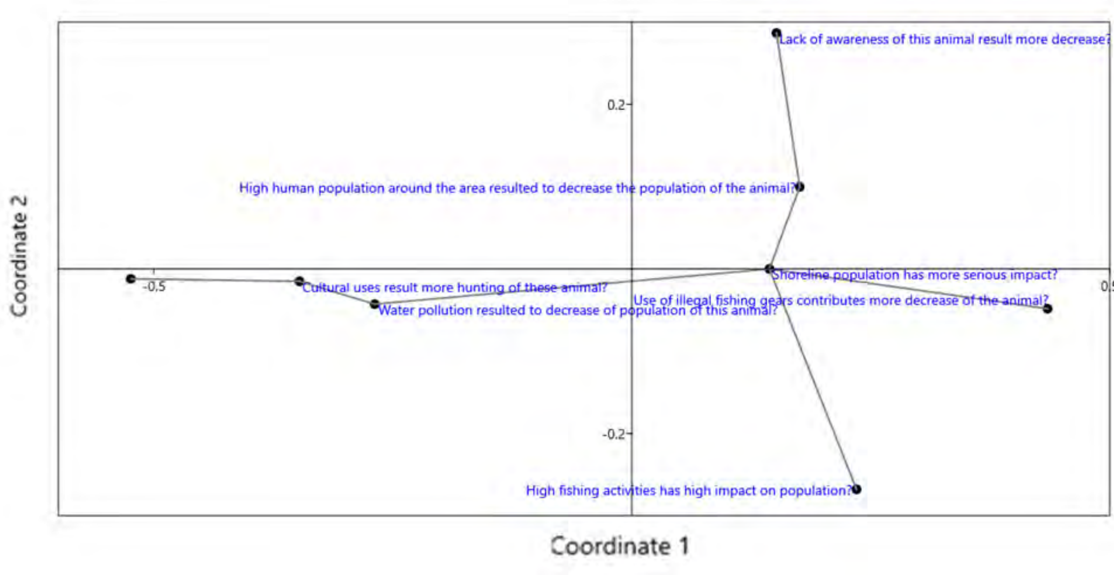

Fig. 3. Non-metric multidimensional scaling (NMD-S) relationship between measured perceptions of the community on threats facing otter.

Problem ranking

The results from PRA show that 50.9% (n = 10) of the respondents agreed that bad fishing activities is leading among the threats raised by the fisherman, this is followed by expansion of human settlement around the dam 24.5% (n = 10). Where by clearing of vegetation and trees around the dam was ranked the third with 14% (n = 10) agricultural activities was ranked the fourth threat by 10% (n = 10) and illegal hunting and livestock keeping was ranked the least one (Table 3).

Table 3: PRA score ranking on threats facing otter in Mtera Dam

SN	Threats	Score	Rank	Percentage
1	Livestock	1	5	0.94
2	Illegal fishing	54	1	50.9
3	Cutting of trees	15	3	14.1
4	Agriculture	10	4	9.4
5	Illegal hunting	00	6	0.0
6	Human settlement	26	2	24.5

Land use/Land cover changes

On the basis of interpretation of remote sensing imagery, field surveys, and existing study area conditions, the researchers categorized the study area into five classes, that is, water, built-up area and bare soil, sparse vegetation, weed vegetation and wood land forest (Fig.4). The study LU/LC changes were estimated from 1998 to 2018. It is evident from figure 4 that the LU/LC changes were of highest amount in wood vegetation from 39% to 76% increase of a half way occurrence to the dam, followed by an increase of sparse vegetation from 0.4% to 18% and built-up area by 4%, between 1998-2007 and 2007-2018. Also, water coverage decreased by 10% from 99% to 89%.

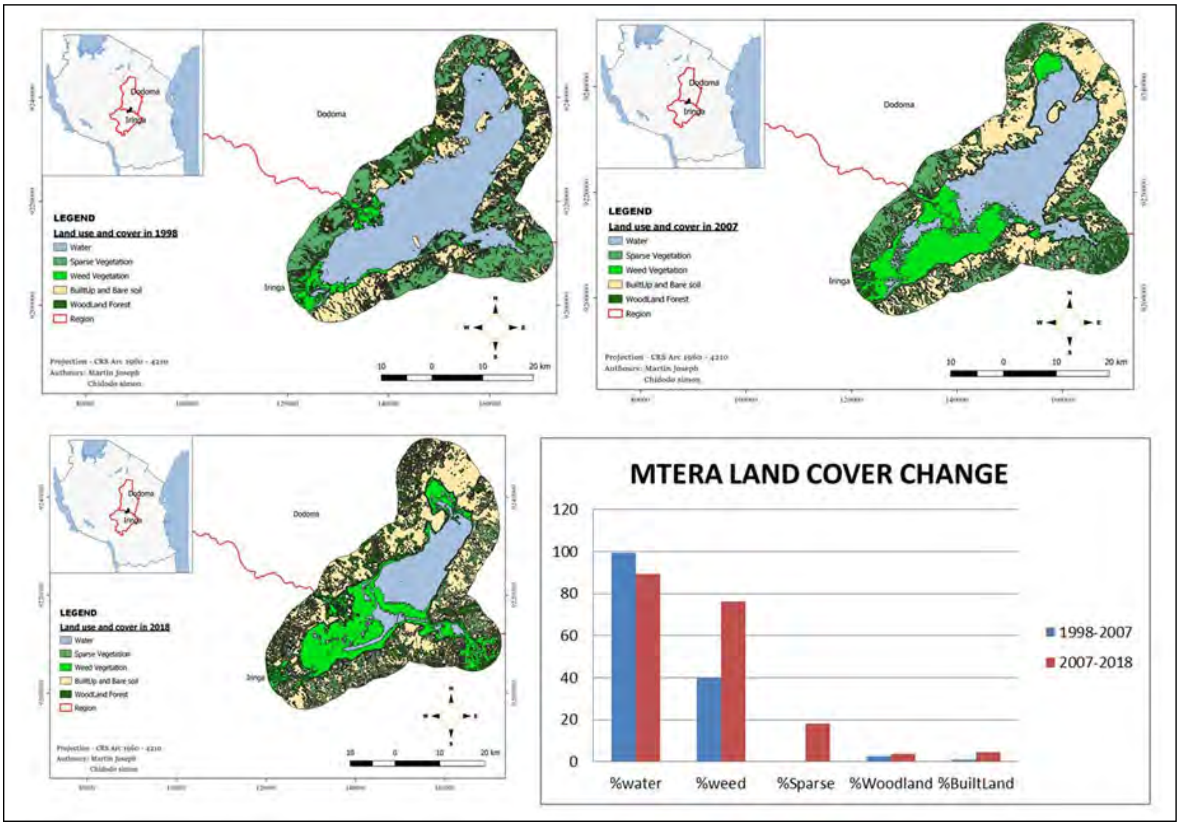

Fig. 4. Land use/land cover change of Mtera dam from 2007 to 2018.

DISCUSSIONS

The study findings show that majority of the fishermen in the study area are aware and knowledgeable about clawless otter. The study also found that majority of the fishermen has a positive attitude towards otter. The finding of this study contradicts with the findings from other studies conducted on otter. For instance, the study conducted by Stevens (2011), Akapona et al., (2015) & Ergete *et al*., (2017) found that fishermen had negative perceptions and dislike otter. The respondents in the study area seem to show a positive attitude towards otter because they afraid of being evicted from the area or being banned by the government from fishing in that particular dam.

The study findings suggest that the distribution of African clawless otter has declined due to changes in habitat cover and threats caused by illegal fishing, increased human settlement and pollution around the dam. The evidence of the threats is justified by the presence of various signs (rolling places, dens, scats or latrines and foot print) that were observed in the study area. These findings are consistent with the findings from the study conducted by Perrin & Carugati, (2000) & De Luca *et al*. (2018) who found that otter avoid mostly area with short grass and prefer riverine habitat cover with dense vegetation.

The results of the Likert scale in NMDs and PRA show that fishermen in the study area did not perceive agricultural activities, cultural uses of otter and water pollution as a major threat to otter unlike De Luca et al. (2018) who found that among the factors contribute to otter declining are water pollution caused by agriculture activities near the water sources, illegal hunting of otter due to influence from traditional belief (medicinal, food and wealth). The difference in the result might be due to low awareness of the ecology of this species and actually low species density (fig.2: showing a very restricted distribution of otter in Mtera dam) whereby they can have low significance impact in the area.

Use of illegal fishing gears, intensified fishing activities, lack of awareness about otter and increase in shoreline population were among the major threats to the survival of otter as indicated by NMD method. These findings are consistent with the findings from previous studies such asSomers & Purves (1996), Perrin & Carugati (2000). According to Kingdon (1997), otter require a very cool, less disturbed and clean water for reproduction and growth. Lack of awareness and knowledge on the ecology of otter results into the use of illegal fishing gears, pollution on the dam bank and clearing the riparian vegetation for fire wood used to dry fish and fresh water prawns.

In terms of land cover and land use change this study has observed that weed had increased tremendously in the study area followed by sparse vegetation and increased in built-up area or bare land soil. These changes are considered to be threats to otter since the increased vegetation causes decrease in food quantity and quality, causing water pollution and high human and noise disturbance due to disappearance of the riparian vegetation and hence increased in built up and sparse vegetation. The changes observed as threats in this study were also pointed out by Perrin & Carugati (2000). De Luca *et al* (2018) recommend that changes occurring in habitat quality have to be well managed by the responsible authorities since they cause major threats to the survival, reproduction and distribution of otter.

CONCLUSIONS AND RECOMMENDATIONS

Generally, conservation status of otter in Mtera dam is at the alarming stage. Despite fishermen being aware of the species, their ecological needs are still not well known and managed. The distribution of otter is significantly affected by the changes occurring in land use. Hence management of these threats in terms of provision of conservation education to fishermen together with proper supervision of fishing behavior might result into positive thriving of otter in the area. More studies on the ecology and population distribution of otter need and documented frequently. Studies such as otter and their habitat quality characterization and preference, competition and coexistence of the sympatric species and human influence in the occurrence of Otter species in different habitats will be of significance importance for the conservation of otter. The study recommends that species that are found outside protected areas should be accounted in conservation similar to those inhabiting the protected areas.

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DIVERSITY OF AQUATIC MACRO-INVERTEBRATES INHABITING THE MOROGORO RIVER ALONG THE GRADIENT OF HUMAN DISTURBANCES

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ABSTRACT

Aquatic macro-invertebrates are organism that live in water and are usually visible with our naked eyes but they lack an internal skeleton. These include insect in their larva and nymph form, worms, snails, mollusks, and crustacean. Specifically this study was aimed at determining the diversity and abundance of aquatic macro-invertebrates in relation to anthropogenic activities carried out along the river. Sweep net was used to collect aquatic macro-invertebrates. The Morogoro River was categorized into three sampling points in accordance to anthropogenic activities that were less human impacted site, moderate human impacted site, and highly human impacted site. The results show that there were 15 species of aquatic macro-invertebrates belonging to 15 families and 11 orders where majority of them occur in the highly human impacted site because they could tolerate such conditions. While, the diversity of aquatic macro-invertebrates was higher in the moderate human disturbed area compared to other areas because of less pollutants in the area and the capacity of those organisms to tolerate the impact caused by human disturbances.

Therefore, this study concludes that the increased in total abundance of the macro-invertebrates along the Morogoro river does not necessarily depict better environment management but rather due to mild human disturbance that favors some tolerant taxa with subsequent reduction of sensitive taxa. Moreover, more species and abundance of the macro invertebrates were moderate tolerant species based on water pollution toleration. Also, the diversity of the macro-invertebrates along the River depends on the intensity and level of the human disturbances. This study recommends that the relevant authorities should regularly monitor and control sources of pollutant and there should be the protection of the river through regulation.

Keywords: Aquatic, disturbance, diversity, human, macro-invertebrates.

INTRODUCTION

Aquatic macro-invertebrates are organism that live in water and are usually visible with our naked eyes without the use of microscope but they lack an internal skeleton. Examples of these organisms include insect in their larva and nymph form, worms, snails, mollusks, and crustacean (Agouridis *et al*., 2015). These organisms are integral part of food chain and without these creatures entire aquatic food web would collapse (Agouridis *et al*., 2015). Furthermore, they are good indicator of water quality through looking on their abundance. Previous studies have shown that streams, rivers, wetlands and lakes are home of the aquatics macro-invertebrates (Mbaruku, 2016) but a number of river and streams flow in urbanized area across the world are profound impacted by change associated with urbanization hence there is a need for restoration (Palmer *et al*., 2007).

The Morogoro river for example, which occurs at low lying point of landscape in Morogoro town make it prone and very sensitive to pollution as the result of human disturbances caused by urban development's and other anthropogenic activities. This in turn results into increased pollutant load through surface runoff, excessive loading of domestics' wastes, hence alter the physical, chemical, and biological characteristics of aquatics systems beyond their natural self-purification capacity (Palmer *et al*., 2007). Despite of the river being polluted but there is lack of information concerning its aquatic ecosystem especially the macro-invertebrates it inhabits. Therefore, this study aimed at determining the current status of macro-invertebrates and water quality of the river by evaluating the diversity and distribution of macro-invertebrates found in the Morogoro River for the purpose of highlighting their conservation strategies.

MATERIALS AND METHODS

Study Area

The study on the diversity of aquatic macro-invertebrates inhabiting the Morogoro River which is located in Morogoro urban in Morogoro Tanzania (Fig.1) was conducted from 19th march to 21st march 2019. Morogoro River flowing from Uluguru Mountains that serve as source of water supply in Morogoro urban. The River is perennial, flowing throughout the year ensure constant availability of water. The catchment source of River Morogoro is the forest around near Bondwa Peak (6.3 km away from Morogoro town) which is the one of the peaks of Uluguru Mountain (Mourice & Mbunde, 2011). Morogoro urban is characterized by tropical climate, most precipitation falls in April, with an average rainfall of 191 mm while the dried month is August with average rainfall of 13 mm which results to the average rainfall of 935 mm per year. It has the average temperature of 24.6˚C (Mourice & Mbunde, 2011). Morogoro is a town with a population of 315, 866 (2012 census) in the eastern part of Tanzania. In the area there is potential to grow subtropical annual and perennial crops in the mountainous areas and tropical annual and perennial crops in the low-lying plains. The most important annual crops in the region are maize, sorghum, millet, rice, potatoes, beans, pulses and oilseeds. The most important perennial crops are sisal and a number of fruit trees. Important vegetables grown are cabbage, carrots, tomatoes, pepper and amaranthus.

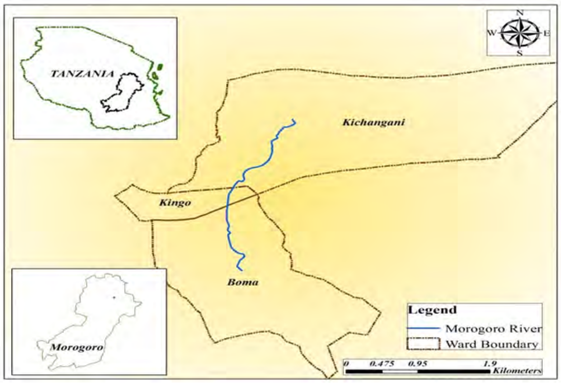

Fig. 1. Map showing Morogoro River passing through three wards that are in all three samplings sites

Data Collection

Sampling site for data collection was selected or established based on the presence or absence of sustained anthropogenic activities conducted along Morogoro River and level of water and habitat quality. The River was classified into three sampling sites based on the impact of anthropogenic activities conducted that was less impacted, moderate impacted and highly impacted sites. Aquatic macro-invertebrates were collected using sweep net in every three sampling sites in order to get species list and their relative abundance (Shilla & Shilla, 2011). The collected macro-invertebrates were counted, and then sample were picked and stored into the bottle of 10% formalin and thereafter identified into species level and recorded. Identification was done by the aid of the identification key and macro-invertebrate guide book. Macro-invertebrates richness and diversity were assessed by 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:

$H' = -\sum_{i=1}^{s} p_i \, [\ln(p_i)]$

H'-Shannon's diversity index
S:-Total number of Species in the community
Pi: Proportion of S made up of the i species
Lnpi: Equitability

Data Analysis

The data collected was used to calculate diversity of Macro-invertebrates using Shannon winner diversity index (Shannon & Winner, 1949). Species diversity help us to know which species is highly distributed and can be calculated by using $H= (Pi) \ln (Pi)$. Then $Pi= ni/N$, where ni = Number of individual of species, Pi=relative abundance of species, N = total number of individual in all species. Then $H'=-\sum pi [\ln (pi)]$, where H'= Shannon diversity index. Randomization test were used to compare the significant different in diversity indices within sampling points. Then classification of Macro-invertebrates based on level of pollution was done, as some of the Macro-invertebrates were very sensitive to pollution, while others were tolerant to moderate level of pollution, and others could live in highly polluted area. A family level water pollution index based on known tolerance of aquatics macro-invertebrate families to various pollutants was worked out by the standards methods which is ASPT (Average Score per Taxon)(Barman & Gupta, 2015).

RESULTS

Aquatic Macro-Invertebrates Abundance

The study revealed the presence of 15 species of aquatic macro-invertebrates which belonged to the 15 families and 11 orders (Table 1). The orders are ephemeroptera, coleoptera, plecoptera, odonata, trichoptera, decapoda, diptera, melagoptera, isopoda, hemiptera and aranaea. The families are veliidae, gyrinidae, psephenidae, baetidae, nemouridae, hydropyschedae, potamonautidae, chironomidae simuliidae, silisidae, oniscidae, armadillidae, coenagrionidae, aeshnidae, and argryronetidae. In the less impacted site, 2 species belong to 2 orders (hemiptera, and coleoptera) were encountered while 6 species of 6 orders(ephemeroptera, plecoptera, odonata, trichoptera, decapoda, diptera) in the moderate impacted site and in highly impacted

Table 1: Classification of aquatic macro-invertebrates in relation to sampling sites

Order	Family	Genus	Less impacted sites	Moderate impacted sites	Highly impacted sites
Hemiptera	Veliidae	Rhagovelia	+	-	-
Coleoptera	Gyrinidae	Orectogyrus	+	-	-
	Psephenidae	Psephenus	-	-	+
Ephemeroptera	Baetidae	Ephemera	-	+	-
Plecoptera	Nemouridae	Nemouris	-	+	-
Trichoptera	Hydropyschedae	Hydropysche	-	+	-
Decapoda	Chironomidae	Simulium	-	+	+
	Simuliidae	Sialis	-	+	+
Melagoptera	Oniscidae	Oniscus	-	-	+
Isopoda	Armadillidiida	Armadillidiidium	-	-	+
Odonata	Coenagrionidea	Nehallenina	-	+	+
	Aeshnidae	Aeshni	-	+	+
Araneae	Argyronetidae	Argyroneta	-	+	+

+ Means presence of Aquatic Macro-invertebrates in a certain site, - means absence of those aquatic macro-invertebrates in that site.

Aquatic macro-invertebrate abundance

Morogoro River is dominated by group of macro-invertebrates such as whirling beetles, broad shouldered water striders, midge, damselfly, stonefly, may fly, blackfly and aquatic pill bug (Tab. 2) according to different water pollution tolerant. More species and abundance of the macro invertebrates were moderate tolerant species based on water pollution toleration (Table 2).

There was similarity of species abundance between moderate and highly impacted site which shows close similarity of percentage abundance of aquatic macro-invertebrates compared to less impacted site.

Aquatic Macro-Invertebrate Diversity

The diversity index of aquatic macro-invertebrates obtained in the site 01 was H’= 0.68 which was the lowest value, followed by site 02, with the diversity of H’= 1.75 which was the highest value and site 03 with the diversity of H’= 1.64 (Tab. 3). Randomization test for significant difference between indices showed significant difference along three sampling point though there is a similar significant difference between sampling point 02 which is moderate impacted site and sampling site 03 which is highly impacted site as shown in (Tab. 3).

Table 2: The group of macro-invertebrates based on water pollution tolerant species

Group	Collected macro-invertebrates	Total number of species	Abundance (%)
Pollution sensitive organism	Broad shouldered water striders	15	12.22
	Whirligig beetles	20	16.26
Total		35	
Moderate tolerant species	Mayfly larva	7	5.69
	Stonefly	5	4.07
	Damselfly	11	8.94
	Caddisfly	5	4.07
	Crab	5	4.07
	Midge	14	11.38
	spider	1	0.81
Total		48	
Pollution tolerant species	Aquatic pill bugs	10	8.13
	Sowbugs	8	6.50
	Water penny bettles	2	1.63
	Blackfly	12	9.76
	Alderfly	3	2.44
	Dragonfly	5	4.07
Total		40	
Total no. of all invertebrates		123	

Table 3: Diversity indices of aquatic macro-invertebrates in three sampling point

SN	Diversity indices	Sampling point 01	Sampling point 02	Sampling point 03
1	Species	2	7	6
2	Shannon diversity	0.68	1.75	1.64

Anthropogenic activities along the River

Morogoro River has the following anthropogenic activities in accordance with three sampling points selected (Tab. 4). The result shows there is a difference between three sampling sites as there is sampling site with no any anthropogenic activities along river compared to remaining two sites moderates and highly impacted site.

Table 4: Classification of different anthropogenic activities in relation to sampling site

Sampling point 01	Sampling point 02	Sampling point 03
None	Farming	Washing
	Car washing	Farming
		Damping

DISCUSSION

Our results revealed that the Morogoro River is dominated by group of macro-invertebrates such as whirling beetles, broad shouldered water striders, midge, damselfly, stonefly, mayfly, blackfly and aquatic pill bug according to different levels of human disturbances. High abundance of species was observed in moderate impacted site which was consisted of the moderate pollution sensitive organisms that can survive in fair pollution water quality because their habitat requirement are not as strict as pollution sensitive organisms. Hence,this finding concurs with the previous one which supported that the presence of macro-invertebrates in the Morogoro River was an indication that the aquatic environment of River was moderately polluted (Camargo, 2019).

The study also showed that the increased in total abundance of the macro-invertebrates does not necessarily depict better environment conditions but rather might be due to mild disturbance that favors some tolerant taxa with subsequent reduction of sensitive taxa. Presence of least sensitive taxa to pollution (i.e., Chironomids) in both two moderate to highly impacted site categories further suggests the notion that they are good colonizers and thus why they appear under a range of conditions. This is because, highly impacted sites cannot provide suitable habitat for very sensitive macro-invertebrates but the Chironomids are able to withstand such a high levels of organic pollution due to their high hemoglobin affinity (Elias *et al*., 2014).

In highly impacted site which was consisted of highly pollution tolerant organisms also has high abundance compared to less and moderate impacted sites due to the presence of different anthropogenic activities which impacted those sensitive organisms and therefore supported only the tolerant ones. Moreover, the abundance of highly pollution tolerant organisms also correlates with the amount of detritus or fine particulate organic matter in the sediment as they are considered tolerable(Elias *et al.*, 2014). This is in support with finding from the previous study which revealed that the presence of Dipteran family Chironomidae and midge larvae family may also be more effective indicators of increased stress due to their abundance domination in impacted sites compared to other families (Eggermont *et al.*, 2003). On other hand, less impacted sites showed to harbor very sensitive organisms toward pollution because of the lowest abundance it had and this might be due to those organisms fail to survive as they require clean water with enough oxygen. As some of them example mayflies are filter feeder which general prefer clean water to facilitate filtering (Barman & Gupta, 2015).

In this study also, it was found that there was high diversity of aquatic macro-invertebrate in moderate polluted site because of less pollutants in the area and the capacity of the organisms to tolerate the impact caused by pollution and also fluctuation of aquatic macro-invertebrates abundance and diversity are caused by food availability and macro-climate together with micro-climatic change (Barman & Gupta, 2015).The less polluted site showed to harbor low diversity of organisms as these organisms were very sensitive to pollution and also because of the absence of anthropogenic activities which increase stream environmental pollution along river such as farming, damping and washing. While, in highly impacted site, the diversity of aquatic macro-invertebrates was medium because probably of the presence of highly tolerant organisms such as blackfly. Apart from revealed the Aquatic macro-invertebrates in the Morogoro River but there were some vertebrates found in the river such as the min now species and frogs. This implied the ecological relationship which describes interaction between and among organisms as the characteristic of health stream which support large and diverse of population of different species both plant and animal (Agouridis *et al.*, 2015). This is because the presence of minnow species and frogs may indicate that the aquatic macro-invertebrates are used as food for these vertebrates and therefore enhance ecosystem balance.

CONCLUSION AND RECOMMENDATIONS

In conclusion, this study shows that the increased total abundance of the macro-invertebrates in the river does not necessarily depict better environment management conditions but rather due to mild disturbance that favors some tolerant taxa with subsequent reduction of sensitive taxa. Macro-invertebrates organisms were shown to be potentially good quality indicators in Morogoro River and remarkably high number of taxa collected could be interesting source of information. However I recommend that there is a need of more intensive study on the entire length of other Tanzania river basins comprehends fresh water organisms andalso that the relevant authorities should regularly monitor and control sources of pollutant along the river and there should be the protection of the river through regulation.

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ASSESSMENT OF NATURE, EXTENT AND TREND OF GIRAFFE SKIN DISEASE IN TARANGIRE-MANYARA ECOSYSTEMS

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ABSTRACT

Giraffe is a crucial species in the ecosystems and tourism industry within the country. Currently are threatened by a disease known as Giraffe Skin Disease (GSD). A three-month study was conducted to assess the nature, extent and trend of skin disease in giraffes inhabiting the Tarangire-Manyara Ecosystems. A cross-sectional roads transect survey was conducted within the parks, where by animals were observed using binoculars from the vehicle. In additional to field surveys, a systematic literature reviews were also done. Emphasis was to observe the disease infestations (number affected in the group) and its severity in relation to sex and age categories. Results showed that prevalence of 69% of the studied population were affected. Lesions were observed at the carpel joint of the fore leg and hind leg as well as the brisket area. Furthermore, our survey indicated infestation to be involving adults (67.8%) and sub adults (1.2%) and there was no visible sign to the calves. Both field and literatures survey indicated marked variation in extent and rate of GSD occurrence. We thus propose further studies including histological characterization to determine the degree of severity in Tarangire-Manyara Ecosystem in comparison to other ecosystems.

Keywords: Giraffe skin disease, lesion, prevalences, transect survey.

INTRODUCTION

Tanzania is unique among the African countries as it has managed to maintain an extraordinary diverse of large wild herbivores including Giraffes (*Giraffa camelopardalis tippelskirchi*). Diseases, illegal hunting and anthropogenic factors have always been the issues, resulting to dramatic decline of large herbivore species. Giraffes (*Giraffa camelopardalis tippelskirchi*) is one of the charismatic large herbivore, endemic to many ecosystems in Tanzania and popular animals attracting tourists to watch in the wild (Bercovitch & Deacon, 2015; Muller, 2016) and thus contributing to the national economy.

For the past three decades, the population of giraffes has been declining to the extent of putting the species at risk of disappearance if unchecked (Muller, 2016). A demographic study done,revealed significant drop in Maasai giraffe population from 66,000 to the existing estimate of 31,000 individuals in the years 1977-1980 and 2015 respectively (Lee & Bolger, 2017). Diseases, poaching as well as habitat loss due to land conversions are the main factors for the decline (Nyamasyo & Kihima, 2014).

Currently, giraffes are affected by strange skin condition, which has been named as Giraffe Skin Disease (GSD). Within Tanzania, the disease was first observed in Ruaha National Park around year 2000, in which about 86% of the giraffe population had visible skin lesions (Epaphras *et al*, 2012). Field observations, coupled with studies revealed the GSD to be spreading from south to the northern protected areas affecting Tarangire-Manyara and Serengeti ecosystems population. Surveys have revealed that Tarangire alone had about 79% of the giraffe population showing the skin lesions (Bond *et al*, 2016)
Decreasing populations become more vulnerable to stochastic factors, especially diseases that can negatively impact the giraffe species and consequently adversely affect economic revenues accrued from tourism. Being one of the important ecosystems in both local and international tourism, Tarangire-Manyara and its surroundings support a relatively large number of giraffes which their conservation is of paramount importance. The occurrence of GSD in Tarangire-Manyara ecosystem will increasing number of weak individuals, upset the social interaction of the species and reduce reproduction performance rate and contribute to giraffe population declining. This study therefore aims to assess the nature, extent and trend of GSD for the past five years. Specifically, we wanted to know how geographical locations, disease status and grades of the lesions relate with age class, sex and part of the body affected by GSD in Tarangire-Manyara ecosystem.

MATERIALS AND METHODS

The study area and study species

The study was carried out in Tarangire-Manyara Ecosystem which covers Lake Manyara NP (330 sq.km) and protected areas such as Burunge WMA), Lolksale GCA, Nou Forest Reserve, Simanjiro Game Reserve and Tarangire NP (Fig.1). Tarangire-Manyara is essential andvital ecosystem as it harbors large wild herbivores of different specieslike giraffes, African elephants (*Loxodonta africana*), buffaloes (*Syncerus caffe*r), oryx, (*Oryx beisa*), zebra (*Equus burchelli*), wildebeest (Connochaetes taurinus) as well as carnivore species includinglions (*Panthera leo*), leopards (*Panthera pardus*) and good number ofbirds such as ostriches, flamingoesand flora of different speciesthat make the ecosystem be endowed with suitable habitats for diversity of fauna species. Six sites were established (Fig.1), which portray various conservation areasnamely, Tarangire National Park (TNP), Lokisale Game Controlled Area (LGCA), Nou Forest Reserve, Burunge Wildlife Management Area (WMA), Lake Manyara National Park (LMNP) and Simanjiro Game Controlled Area (SGCA).

Giraffes species are sexually dimorphic animals, in which males are giant, stay in detached groups, territorial less and very worried animals (Marealle *et al*, 2010). They can move up to 5 kilometers per day, normallyinterchange the sites frequently, males roam much than females (Jeugd & Prins, 2000). Males feedon thickets while females, calves together with youths browse on open environment where they can increase vigilance to escapepredators(Strauss & Packer, 2013). Their main natural enemies are African lions, leopards, poachers and diseases (Karimuribo *et al*., 2011; Lee & Bond, 2015; Lee & Bolger, 2017).

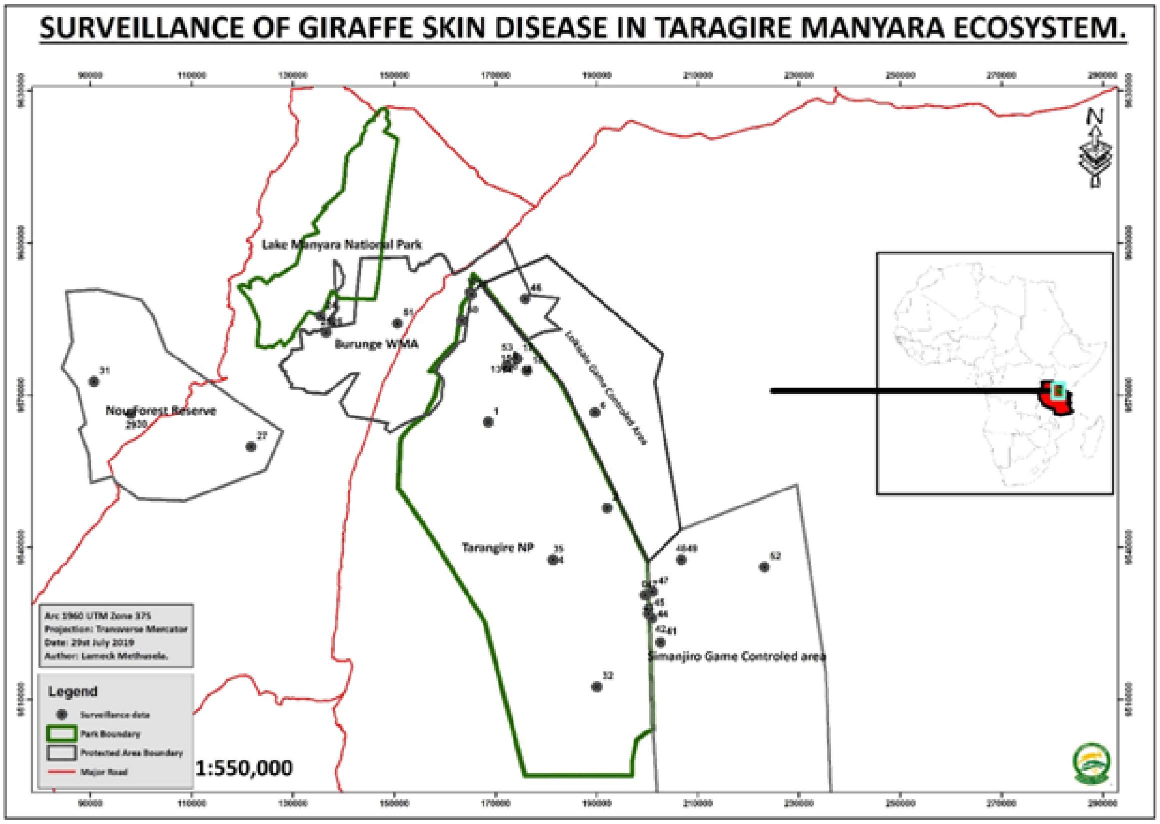

Fig. 1. Map of Tarangire-Manyara ecosystem showing study sites

Assessment of Giraffe Skin Disease

Giraffe observation survey was carried out from February to April 2019 by using road transect. The transect were laid down based on accessibility of protected areas road network. The encountered rate determined through direct observation in the field along the roads. Two researchers were equipped with binoculars and hand held global positioning system (GPS) units, sitting on the middle sit of the car observing each side of the transect. The car was driven on maximum speed of 20 km/h and any individual or group of giraffes sighted the car was stopped for observation of each individual for the skin lesion sign. Observation of giraffes were done during the morning and evening time or when the weather was cool to maximize sighting as the animal activity will be high compared to the hot part of the day. Binoculars were used for the animals sighted in a distance that would not give clear observation using eyes. Parameters taken into consideration during observation include size of the group, sign of skin condition, location of the lesion on the body, age and sex of the affected individual. By using hand held GPS, the location of individual encountered were also recorded. The observation lasted for at least within 15 minutes and when a giraffe disappeared before the first 15 minutes of observation was achieved, the stop watch was stopped and that was the end of observation for that particular giraffe.

Giraffes were categorized according to sex and three age classes; calves which stay with their mothers, their skin look like slightly folded or wrinkled, eyes and ears are large relative to the face. Sub adult their coat improves, develop smoothness, no wrinkles, characteristically clear, eyes and ears are smaller relative to the head with small ossicones having black hairs at their tips. While adult giraffes have tight skin on the face and jaw areas, the coat color is darkening with mane waving (Strauss, 2014).

Data Analysis

The data were entered in Excel spreadsheet and the same Microsoft excel was used during the analysis. Nature and extent of GSD was calculated as percentage, giraffes with skin lesions over total number of giraffes observed throughout cross section study in 6 sites were computed. The relationship between gender, disease status and part of the body affected were considered. Chi -squared test was used to justify statistical significance between comparative of categorical variables studied.

RESULTS

A total of 84 giraffes in 16 groups were sighted and observed in 6 sites over a span of 3 months (February to April, 2019). Within these observations there were 3 categories that were considered namely, disease status, part of the body affected and age class with respect to location (Table.1). The overall GSD prevalence in Tarangire-Manyara ecosystems was 69% which shows more than half of the giraffe encountered were affected by skin disease. The disease prevalence was high in adult giraffes (67.8%) compared to sub-adult (1.2%) and none to the calves. Tarangire National Park had high number of affected individuals (32%) than any other surveyed site and female giraffes were frequently sighted than males (Table 4). The study established that among the diseased giraffes, 40% of females and 29% of males had clear sign of GSD while 31% were not affected in the Tarangire-Manyara Ecosystem. There are strong correlation between disease status and part of the body affected by GSD in the ecosystem.

During the survey in Tarangire-Manyara ecosystem in February-April 2019, majority of giraffes sampled were adult 84% (Table 1) with minimum number of sub-adults and calves. Females observed were more (52.4%) than males (47.6%) (Table 2).

Table 1: GSD prevalence (%) in TME with respect to age group and sex (N=84)

	Variable	Number (n)	Percentage (%)
Age class	Adults	57	67.85
	Sub adults	1	1.19
	Calves	0	0
Sex	Female	34	40.47
	Male	24	28.57
GSD prevelence	Disease (+ve)	58	69.04
	Disease (-ve)	26	30.95

Table 2: Distribution of Giraffe Skin Disease with respect to part of the body affected in Tarangire-Manyara Ecosystems (N=84).

Sex	Part affected	Tarangire NP	Burunge WMA	Nou Forest Reserve	Simanjiro GCA	Lake Manyara NP	Loksale GCA
Female (n)%	Fore limb (27) 32.14	(14) 16.67	(1) 1.19	(5) 5.95	(4) 4.76	(1)1.19	(2) 2.38
	Hind limb (7) 8.33	(5) 5.95	(1) 1.19	(1) 1.19	(0) 0	(0) 0	(0) 0
	Brisket (3) 3.57	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0
Male n(%)	Fore limbs (15) 17.85 Brisket(0) 0	(7) 8.33	(5) 5.95	(1) 1.19	(2) 2.38	(0)0	(0)0
	Hind limb (6) 7.14	(0)0	(4) 4.76	(1) 1.19	(1) 1.19	(0)0	(0)0
	Brisket (3) 3.57	(0)0	(1) 1.19	(0)0	(0)0	(0)0	(0)0

Disease status had 4 grades, these are non-symptomatic (disease negative), mild when the lesion is in initial stage appear as a nodule estimated to less than 5cm, moderate meant wound with less than 10cm and severe meant a wound estimated range from 11-15 cm and above (Epaphras *et al*., 2012), discharging some fluids, crumpled skin or raw fissures (Table 3). The recorded 43 female individuals, 34 fell within diseased animals with mild, moderate or severe grades of wounds. During this time 41males were viewed in which 24 animals had sign of the skin disease. In terms of GSD severity,the observed animals were categorized in relation to disease status. The overall GSD prevalence in the Tarangire–Manyara Ecosystem was 69% which shows more than half of the giraffes were affected by skin disease.

Table3: Location distribution of GSD shows (%) disease status (N=84)

Disease status	Site names (n)%					
	Burunge WMA	Lilksale	Nou Forest Reserve	Simanjiro GR	Lake Manyara NP	Tarangire NP
Mid	(6) 7.14	(1) 1.19	(3) 3.57	(3) 3.57		(8) 9.52
Moderate	(5) 5.95	(1) 1.19	(3) 3.57	(3) 3.57		(13) 15.47
Severe	(2) 2.38	(0) 0	(4) 4.76	(1) 1.19		(5) 5.95

Table 4: Data collected in Tarangire –Manyara Ecosystem in % in different years

2015/2016	Site	Number of giraffes	Prevalence	Mild	Moderate	Severe
	Lolkisale	42	69	12	38	19
	Lake Manyara NP	50	00	00	00	00
	TNP	382	79	33	24	23
Febr-April 2019	TME	84	69	25	30	14

DISCUSSION

Across Africa where giraffes are endemic,GSD varies in severity and occurrences. We report the overall prevalence of GSD of 69%in the Tarangire-Manyara ecosystems, which shows more than half of the giraffe encountered were affected by skin disease. The disease prevalence was high in adult giraffes (67.8%) compared to sub-adult (1.2%) and none to the calves(Table 1). Tarangire National Park had high number of affected individuals (32%) than any other surveyed protected area in the ecosystem, and female giraffes were frequently sighted than males. Elsewhere in Tanzania where Maasai giraffes are found GSD varies in occurrence depending on both region, age and sex.

The study conducted in 2009 in Ruaha National Park showed that the prevalence of GSD was 80%, in which 84.6% of the encountered individuals were adults. Location of the body affected were on fore limbs, hind limbs, hind quartes, vulva area, coffin and brisket area. About 51.4% of male giraffes appeared to be affected more than female which were 48.6%. Overall, among the studied individuals 51.7% had severe lesions (Mpanduji *et al.*, 2011).

The study conducted in March -June 2014 in Tarangire Nation Park showed a prevalence of 61% of GSD and the survey conducted in 2015/2016 in Tarangire-Manyara ecosystems revealed that the prevalence of GSD was 79% in encountered giraffes (Bond *et al.*, 2016b). However, at Lake Manyara National Park, out of 50 individual giraffe encountered there were no any sign of GSD (0%) (Table:4). During the same period, in Tarangire National Parkit indicated that only front legs of giraffes were affected by lesions and 23% had severe cases (Bond *et al.*, 2016).

The affected parts of the giraffe body include the front legs,hind legs and brisket (50%,15.47% and 3.57 % respectively) and 14% of affected animals had severe lesions. Probably other giraffes encountered in 2015/2016 with severe cases might have died because of the severe and advanced infections, lameness or succumbed easily by predators. The data confirmed that most frequent part of the body affected by GSD is at the carpel joint of limbs 50% and the most affected individuals are females, where by the majority of the diseased giraffes were found in Tarangire National Park contrary to Lake Manyara National Park which, had least number of GSD (1.19%) among the six sites studied in Tarangire Manyara ecosystems

In other protected areas such as Burunge WMA, males were affected much on hinds limbs and severe lesions were on the briskets, similarly, Nou Forest Reserve had more males with severe lesions on brisket. Giraffes which had severe cases also had discharges of some fluids in their lesions, stood in one place for long time and walked cautiously when observed at close distance,and surprisingly, males are the only individuals affected on briskets.

In Kenya giraffes (*G. camelopardalis rothschild*) are mostly affected in limbs either fore or hind limb or both. South Africa, Zimbabwe and Botswana giraffes (*G.c.angolensis*) are affected on upper body, in other countries out of Africa. GSD is also observed on limbs, entire body, head, upper body, testicles and inner thigh (Muneza *et al.*, 2016a).

Conclusion and recommendation

Female giraffes are the most affected animals in fore limbs as was observed in this study while males are affected highly in hind leg and brisket. High magnitude of GSD is in Tarangire National Park,however there was variation in occurrence of GSD by location. Therefore this study displayed the variation in giraffes skin disease and its pattern in Tarangire-Manyara Ecosystems, and differences in GSD exist between sexes, age , part of the body affected and location. The maximum part affected by the disease are the carpel joint of the front leg for both females and males. Only males are affected on brisket and they had severe cases than females in Tarangire-Manyara ecosystem. There was strong positive correlation link between disease status of the lesions and part of the body affected by GSD. Future study should be directed toward histological characterization to determine the degree of severity of GSD by comparing different ecosystems.

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CARNIVORE PARVOVIRUS ECOLOGY IN THE SERENGETI ECOSYSTEM: VACCINE STRAINS CIRCULATING AND NEW HOST SPECIES IDENTIFIED

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ABSTRACT

Carnivore parvoviruses infect wild and domestic carnivores and cross- species transmission is believed to occur. However, viral dynamics are not well understood nor the consequences to wild carnivore populations of the introduction of new strains into wild ecosystems. To clarify the ecology of these viruses in a multi-host system such as the Serengeti ecosystem and identify potential threats for wildlife conservation we analyzed, through real-time PCR, 152 samples belonging to 14 wild carnivore species and 62 samples from healthy domestic dogs. We detected parvovirus DNA in several wildlife tissues. Of the wild carnivore and domestic dog samples tested, 13% and 43%, respectively, were positive for carnivore parvovirus infection, but little evidence of transmission between the wild and domestic carnivores was detected. Instead, we describe two different epidemiological scenarios with separated routes of transmission: first, an endemic feline parvovirus (FPV) route of transmission maintained by wild carnivores inside the Serengeti National Park (SNP); and second, a canine parvovirus (CPV) route of transmission among domestic dogs living around the periphery of the SNP. Twelve FPV sequences were characterized, new host-virus associations involving wild dogs, jackals and hyaenas were discovered and our results suggest mutations in the fragment of the vp2 gene were not required to infect different carnivore species. In domestic dogs, six sequences belonged to the CPV-2a strain, whilst 11 belonged to the CPV-2 vaccine-derived strain. This is the first description of a vaccine-derived parvovirus strain being transmitted naturally.

Keywords: Carnivore parvovirus, Serengeti ecosystem, vaccine-derived parvovirus strain, wild carnivore

INTRODUCTION

The species Carnivore protoparvovirus known colloquially as the Carnivore parvoviruses, is a member of the Parvoviridae family and includes the antigenic variants feline and canine parvovirus (FPV and CPV).Carnivore parvoviruses infect a wide variety of host species with complex pathological and epidemiological outcomes. They have a broad tropism for mitotically active cells and, depending on the strain, presence of co-infection with other pathogens, and specific characteristics of the host, such as age, species and host immunity, can cause sub-clinical, acute or, especially in young animals, lethal disease (Hoelzer et al., 2008).

Carnivore parvoviruses have a global distribution and are present in apparently healthy individuals from almost all wild and domestic carnivore populations tested (Duarte et al., 2013; Allison *et al.*, 2014). In contrast, there are reports that implicate the introduction of these viruses into wild ecosystems with the decrease in naive populations (e.g. wolves (*Canis lupus*) (Mech & Goyal, 1995). Despite this apparent ubiquity and variable pathogenicity, understanding of Carnivore parvovirus evolution, strain succession and spread is based upon a limited number of studies, mostly involving diseased captive wild and domestic animals (Hueffer *et al*., 2003). These complexities illustrate the difficulties of predicting the consequences of infection at an individual and a population level,especially in wild ecosystems where multiple potential hosts may reside. In order to better understand which wild species are at risk of infection and optimize conservation measures, it is necessary to further investigate the dynamics of Carnivore parvoviruses.

Although FPV and CPV share a recent common ancestor from the early 1900s(Allison *et al*., 2014) and are differentiated by only small genetic changes, they show several important differences. Known since the 1920s (Verge & Christoforoni, 1928), FPVis primarily associated with infection in felines rather than canines (with the exception of foxes), and has also been shown to infect Herpestidae, Mustelidae and Procyonidae (Duarte *et al.*, 2013). In contrast, canine parvovirus (CPV), which was first reported in the 1970s (Appel *et al.*, 1979), shows signs of a recent population expansion and, whilst infection is intimately linked with domestic dog (*Canis lupus familiaris*) populations, the virus has been described in a wide range of species, including felines (Shackelton *et al*., 2005; Hoelzer *et al*., 2008).

CPV infection in dogs have resulted in the emergence of different antigenic variants or strains: the first strain, designated CPV-2 (Appel *et al.*, 1979), appeared in 1978 and was unable to infect felines. It spread globally and within a few months killed many naive domestic dogs (Truyen *et al*., 1996). A further strain named CPV-2 appeared in 1980 and rapidly substituted CPV-2 worldwide. Whilst only differentiated from CPV-2 by a few amino acid substitutions, the CPV-2a strain regain the ability to infect felines (Truyen *et al.*, 1996). The most recent strains CPV-2b and 2c emerged in 1984 and 2000, respectively, and have only one amino acid substitution each relative to CPV-2a (Hoelzer *et al*., 2008). Today, FPV coexists in different parts of the world with CPV-2a, 2b and 2c with unknown consequences for wild carnivore populations.

In Africa, molecular studies of FPV and CPV in domestic animals were carried out in a limited range of countries (South Africa, Morocco, Tunisia, Ghana and Nigeria)(Steinel *et al*., 2001; Duarte *et al*., 2013) and results are consistent with findings from other regions of the world: CPV-2a, 2b, and 2c strains were circulating within domestic dogs, whilst the original strain CPV-2 has not been detected (Shackelton *et al*., 2005). Further, virus sequences generated from these studies showed a high similarity with strains circulating in the rest of the world, suggesting a similar epidemiological scenario exists in Africa as elsewhere.

Even fewer studies have focused on the role that African wild animals play in Carnivore parvovirus ecology and these have been limited to serological analyses (Steinel *et al*., 2001). These studies have played an important role demonstrating that African wild carnivore species can be infected with Carnivore parvoviruses. However, unlike genetic analyses, serological studies do not enable strain characterization and, because strong antigenic cross-reactions occur among Carnivore parvoviruses, the presence of antibodies does not enable conclusions to be drawn about the strain of the infecting virus (Steinel *et al*., 2001). Therefore, despite some studies concluding wild carnivores have been infected by CPV, it is perhaps more appropriate to conclude that sero positive wild carnivores have at some point been infected by an unspecified Carnivore parvovirus strain.

Genetic techniques provide an opportunity to investigate Carnivore parvovirus ecology with more precision. As with human parvovirus infection, Carnivore parvovirus DNA is likely to persist after the clinical period, increasing the potential for detecting viral infections in archived animal samples. Indeed, the polymorphic vp2 gene, which encodes the protein responsible for binding the transfer in receptor (TfR) used in Carnivore parvovirus host cell attachment, provides a good candidate for molecular analyses and has been used for strain discrimination and to trace viral origins (Allison *et al*., 2014).

The Serengeti ecosystem is an important area for the study of Carnivore parvovirus ecology. First, it hosts large and diverse wild carnivore populations, which can provide critical information about natural infection routes. Second, some species living in the system, such as African wild dogs, are endangered (Woodroffe & Sillero-Zubiri, 2012) and require protection. Third, as mass dog vaccination programs against rabies, canine distemper and CPV have been performed around the periphery of the Serengeti National Park (SNP) since 1996, this environment provides an opportunity to investigate the implications of mass dog vaccination in wild and domestic carnivore populations.

The principal objective of this study was to investigate the molecular epidemiology of Carnivore parvoviruses in domestic and wild carnivores of the Serengeti ecosystem. While serological studies have confirmed the presence of Carnivore parvoviruses infection in lions (*Panthera leo*), hyaenas (*Crocuta crocuta*), jackals (*Canis sp*), wild dogs (L*ycaon pictus*) and domestic dogs (*Canis lupus familiaris*)(Steinel *et al.*, 2001), no molecular studies have yet been carried out to characterize circulating strains in a wide range of potential host species. Within this objective, we aimed to investigate the natural routes of infection in wild and domestic carnivores, the likelihood of cross-species transmission, and potential transmission of Carnivore parvovirus strains found in vaccinated domestic dog populations.

MATERIALS AND METHODS

Sampling

Sample collection was conducted in wild carnivores in Serengeti National Park and indomestic dogs living in villages around the periphery of the SNP including Nyamburi, Merenga, Pinyinyi, Malambo, Kitawasi, Engarasero, Arash and Piyaya.

In addition to that, archived (-20º C) biological samples collected between 2002 and 2011 were used in this study including; i) tissue samples (n = 112) collected during wild carnivore post-mortem examinations carried out in the Serengeti National Park (SNP). Linked GPS coordinate data was available for most of the samples. The cause of death for each of the sampled wild carnivores was unknown;ii) blood samples (n = 40) collected opportunistically from wild carnivores during routine anesthesia immobilization;iii) uncoagulated (EDTA) blood samples (n = 62) collected during mass dog vaccination programs from manually restrained healthy unvaccinated (< 1.5 years old).

One lion (*Panthera leo*) feacal sample was available for testing. It belonged to a spleen-positive adult animal (H440) and was excluded from the statistical analysis.

Molecular analysis

DNA was purified from 50mg of tissue or 200µL of blood in a series of rapid "wash-and-spin" steps, using the High Pure PCR Template™ Preparation Kit (Roche® Diagnostics Gmbh, Mannheim, Germany following the manufacturer´s recommendations. Purified DNA was stored at -80ºC until further use.

To determine the presence of parvovirus DNA (case ascertainment), a previously described real-time PCR(69) (qPCR) was performed. It targeted a conservative parvovirus region of 163 nucleotides and it did not discriminate between different parvovirus strains. In this qPCR, the final mixture of 25 µL contained0.4 µM of primers, 10 µL of Quantiprobe™ (Qiagen® GmbH, New York, USA), 0.4 µM of probe, 3.5 µL of template DNA and free-nuclease water. The assay was performed on a StepOne™ Real-Time PCR System (Foster City, USA).

For the characterization of the Carnivore parvovirus strains, a 1377 portion of the vp2 gene (total length: 1755 bp) was amplified with four nested PCRs. The final mixture of 25µL contained 0,5 µL of primers, 0,25 µL of FastStart Universal Master Mix (Roche™), 1.5 µL of Cl2Mg, 2.5 µL of buffer 10x, 0.5 µL dNTP 10 µM, 4 µL of template DNA and sterile free-nuclease water. Three internal nested PCR reactions amplified three segments of different length, which were subsequently purified. Five primers were used to sequence five overlapping fragments covering a total of 1377 nucleotide residues with the automated Sanger sequencing method.

A 10-2 commercial CPV vaccine dilution (Nobivac® Puppy DP, MSD Animal Health, Carbajosa de la Sagrada, Spain), containing attenuated live CPV-2 virus, was added as a positive control, and sterile free-nuclease water as a negative (blank) control to each step of the molecular analysis.

Sequence data

Blast searches in GenBank® were performed for each sequence generated. Nucleotide sequences were translated into the putative amino acid sequences and position sites were numbered (Reed *et al*. 1988). Specific amino acids were used for classification of the FPV, CPV-2, CPV-2a, CPV-2b and CPV-2c strains (Parrish, 1999). Nucleotide and amino acid sequence pairwise identity was calculated using the online software SIAS® (Sequence Identity and Similarity)(2018). Only sequences > 1300bp were used in this analysis. In addition, template sequences of Carnivore parvoviruses were randomly selected from 1990, 2007 and 2015 and were included for comparison (GenBank® accession no.: M38246, EU145593, KX434462). The 1990 sequence was the oldest one found in the GenBank® database and was included in the study to assess viral diversity over time. Sequences were aligned with the Clustal W method using the MEGA7® software.A maximum-likelihood phylogenetic tree was inferred and the reliability was evaluated with the bootstrap method based on 1000 replicates using the same software. Sequences described in this study were submitted to GenBank® (accession numbers MK251434-MK251461).

Statistical analysis

Statistical analyses were performed using the exact binomial confidence interval (95% confidence level) for prevalence calculations. Associations between the presence of Carnivore parvoviruses DNA and potential explanatory variables, such as type of tissue, species, family, age (young, juvenile, adult), sex and year of collection, were evaluated by binomial logistic regression using the software R®. Variable selection was carried out using manual forward selection based on lowest Akaike information criterion (AIC). Strengths of associations were determined based on odds ratios with 95% confidence limits. Wildlife sample coordinates were used to calculate the distance (km) from the location of sampling of wildlife to the point of nearest human contact, with the location of a) the nearest building and b) the SNP boundary used as proxy measures. QGIS®Geographic information System Software was used for distance calculations and for the representation of sample locations. A binomial logistic regression model was constructed with the proxy measures described above as predictor variables to investigate whether proximity to human habitation and / or the park boundary predicted likelihood of Carnivore parvovirus infection.

RESULTS

Presence of infection in wildlife

The presence of Carnivore parvovirusDNA was confirmed in 13.8% (C.I. 8.7-20.3) (n = 21) of samples, and in 8 out of 13 wild carnivore species tested (Table 1). In four of the five species in which Carnivore parvovirus DNA was not detected, the sample size was low (<7) precluding conclusive inference regarding absence. The species with the highest proportion of infected individuals was the African civet (*Civettictis civetta*),in which 80% (C.I. 28.4-99.5) (n = 5) of samples were positive. No infection was detected in the bat-eared fox (*Otocyon megalotis*), despite the relatively large sample size (n = 15). Of the seven different tissues analyzed, positive results were obtained in six (blood, brain, intestine, liver, lymph node, salivary gland and spleen). The fecal sample from the positive lion, which was added posteriori, was positive to infection. From the binomial regression analysis investigating the determinants of Carnivore parvovirus infection in the samples tested liver samples (OR = 17.8 (95% CI 1.8, 218), p = 0.01) and samples collected from Viverridae (OR = 17.6 (95% CI 3.3, 118), p = 0.001)were significant predictors of infection. The year of sample collection was not a predictor of infection. There was no association between likelihood of sample infection and distance to the nearest building (OR = 1.0 (95% CI 0.98, 1.04), p > 0.3) or the SNP boundary (OR = 1.0 (95% CI 0.99, 1.02), p> 0.1).

Table 1: Percentage of samples from different wild carnivore families and species that were infected with parvovirus DNA, detected by real-time PCR			
	Total	Positive	Percent infected (95% C.I.)
Viverridae (combined)	8	6	75 (34.9-96.8)
African civet	5	4	80 (28.4-99.5)
Genet	3	2	66.7 (9.4-99.2)
Herpestidae	7	1	14.3 (0.4-57.9)
Mongoose	7	1	14.3 (0.4-57.9)
Felidae (combined)	52	6	11.5 (4.4-23.4)
Lion	44	6	13.64 (5.2-27.4)
Cheetah	6	0	0
Leopard	1	0	0
Serval	1	0	0
Canidae (combined)	51	5	9.8 (3.3-21.4)
B-backed jackal	15	2	13.3 (1.7-40.5)
Wild dog	20	3	15 (3.2-37.9)
Bat eared fox	15	0	0
Aardwolf	1	0	0
Hyenas (combined)	34	3	8.8 (1.9-23.7)
Spotted hyena	32	2	6.3 (0.8-20.8)
Striped hyena	2	1	50 (1.3-98.7)
Total	**152**	**21**	**13.8% (8.7-20.3)**

Sequence analysis in wildlife

From a total of 21 positive wild carnivore samples, 13 vp2 gene fragments were sequenced. Ten sequences consisted of 1377 nucleotides, one each of 1311, 1088 and 699 nucleotides. Nucleotides previously used for the classification of Carnivore parvo viruses (20, 38, 39) were present in all these isolates: twelve isolates belonged to the FPV strain (three lions, two spotted hyenas, two African wild dogs, two civets, one genet (*Genetta genetta*), one white-tailed mongoose (I*chneumia albicauda*), and one black-backed jackal (*Canis masomelas*), whilst one isolate belonged to the CPV-2a strain (black-backed jackal). The FPV and CPV-2a isolates detected in black-backed jackals were found in two different individuals. This is the first time FPV DNA has been detected in jackals, hyenas, African wild dogs and white-tailed mongoose. Interestingly, the CPV-2a isolate was detected in the most recently obtained wild carnivore sample (2011). This isolate was the only sequence with intermediate features between FPV-like and CPV-like viruses (detailed in Section 3.1.4.).

FPV in wildlife

Comparison of FPV sequences from this study showed nucleotide identities of 99.5-99.9% (mean 99.75, SD 0.09) and amino acid identities of 99.1-100% (mean 99.61, SD 0.23). This compares with a global blast search in GenBank®

in which no identical FPV sequences were found. Following comparison with the template strains from different years and locations, nucleotide identity was 98.0-99.2% and amino acid identity was 96.9 - 99.8%. The maximum amino acid variability of the study sequences was 0.9%, whilst the maximum amino acid variability between the study and the template sequences was 3.1%, suggesting the study sequences to be more closely related with each other than with sequences found elsewhere.

The FPV sequences detected in wild carnivore species in the Serengeti ecosystem shared two mutations at two different residue positions that distinguish them from FPV sequences described elsewhere. These mutations were located at amino acid position 303, where a Tyr replaced a Phe residue (F303Y), and at position101, where a Thr substituted an Ile residue (I101T). Following comparison with the most similar FPV strains found in GenBank®, the first mutation F303Y was only found in a cougar (Puma concolor) (USA, 1989, GenBank® accession Nº EU659113) and could have arisen independently in this individual. Residue 303 is located in the capsid surface area that contacts with the host cell receptor, and as such this position is subjected to evolutionary selective pressures(34). The second mutation, I101T, which emerged during the differentiation of CPV-2a from CPV-2 (Stucker *et al*., 2012), has occasionally been reported in FPV sequences extracted from wild and domestic species from different years and locations (e.g. GenBank® accession Nº MF069447, FJ440714, KP682520). Polymorphic residue 101 lies just below the capsid surface and, together with residue 87, alters the antigenic structure and influences the binding to feline and canine cells (Stucker *et al*., 2012). Together, amino acid residues 303 and 101 determine host-range and the mutations detected in this study form a geographic cluster, as demonstrated by the phylogenetic network (see below).

A further mutation at position 20, where a Thr substituted an Ala residue (A20T), was presented in three of eight FPV sequences containing this amino acid (belonging to two lions and a mongoose). This mutation was also found in four of the CPV sequences described in dogs sampled in this study (see below). Mutation A20T was not found in any of the most similar FPV strains found in GenBank® and information regarding this residue was lacking in the literature reviewed. We hypothesize that, because residue 20 was located only a few residues from the primer sequence,this mutation could be a sequencing error.

Five other single FPV sequence mutations were found (V83I, Q159H, H222P, V250M, Q296H), each occurring in one sample only. Residues involved were not strain type determinant and no previous studies determining the effects of these substitutions were found.

Among the FPV sequences from this study, two pairs of amino acid sequences were pairwise identical, (i)H414 (lion, liver, 2004) and H284 (white-tailed mongoose, spleen, 2008) and (ii) H450 (hyena, liver, 2007) and H253 (civet, spleen, 2009)). Furthermore, five amino acid sequences (H414, H284, H450, H253 and H440) were only differentiated by a nucleotide at a single position (number 58), which encodes the amino acid residue at position 20, discussed above.

CPV-2a from the black-backed jackal H398

Sequence H398 clustered phylogenetically with the CPV-2a sequences from dogs (see below). However, a single mutation at amino acid position 323 (Asp residue substituted the

CPV-2a-typical Asn or Glu) was present. As the amino acid at this position is exposed on the surface of the virus and controls the interaction with the canine transferrin receptor (TfR) (Allison *et al*., 2014), it is possible that this viral mutation would favor the binding to a feline transferrin receptor.

Furthermore, we described four additional amino acid mutations in this sequence: A20T, R80T, D99H, D125Y. Of these mutations, substitution A20T is shared by eight of our wildlife and domestic dog isolates.

The phylogenetic tree indicated that the FPV strains detected in the wildlife species in this study have a common ancestor, formed a geographic cluster separated widely from other published isolates, and are closely related suggesting cross-species transmission.

Presence of infection in domestic dogs

The presence of Carnivore parvovirus DNA was detected in 42.9% (C.I. 30.5-56.0) (n = 26) of the domestic dog samples assayed and in six of the eight villages (75%) in which sampling took place. The villages with the highest proportion of infected individuals were Merenga (2008) and Kitawasi (2005), in which 87.5% (C.I. 47.3-99.7) and 83.3% (C.I. 35.9-99.6) of dogs sampled were infected, respectively (Figs.2 and 4). None of the factors studied (village, year of sampling, age or gender of dog) were significant predictors of infection (p> 0.4).

Sequence analysis in dogs

From a total of 26 positive domestic dog samples, 13 isolates of 1377 nucleotides and four of approximately 700 nucleotides were obtained. Of these, 11 were classified as CPV-2 and six as CPV-2a. Of the CPV-2 strains, three were found in samples from the village of Kitawasi (2005), six from Merenga (2008), one from Nyamburi (2009), and one from Piyaya (2009). Of the CPV-2a strains, four were detected in Nyamburi (2005, 2006 and 2009), one in Piyaya (2004), and one in Kitawasi (2005) (Figs.2 and 4).CPV-2 and CPV-2a strains were differentiated using the amino acid positions 87, 101, 219, 300, 305, and 375, which are considered determinant residue positions for the classification of the CPV strains(41, 42). Sixteen of the seventeen sequences obtained from domestic dogs fulfilled this classification with no intermediate virus-like features. An exception was the CPV-2 sequence obtained fromisolate H493, which, apart from position 101 in which a Thr was substituted by Ile, presented all the residues that characterize the CPV-2 strain. Position 101 determines the antigenic structure and binding capabilities of the capsid (42), and a Thr at this position is typical of the CPV-2a,2b and 2c strains but has also been described in FPV sequences from GenBank® and in all the FPV sequences described in this study (detailed in Section 3.1.3.). We conclude therefore that the CPV-2 sequence found in H493 presented an intermediate virus-like feature at position 101.

In addition to the six amino acid residues used to differentiate CPV2 from 2a, three further common mutations that differentiate CPV-2 from CPV-2a strains were found. These mutations were located in amino acid positions 219, 297 and 386. Substitution S297A was first detected in 1987 in CPV-2a strains and is reported to be distributed globally (Ohshima *et al.* 2008). All the CPV-2a isolates from this study had this mutation. Mutations I219V and Q386K were found in all the CPV-2 isolates. Although these two mutations were not found in any of the template strains, they were found in the live virus vaccine strain contained in the Nobivac® Puppy DP vaccine, which has been used in mass dog vaccination programs conducted in the study area (GenBank® accession Nº MG264079). These substitutions (of Ile by Val at position 219 and Gln by lysine at position 386) were patented by the manufacturer (US 9,186,398 B2) and introduced in order to attenuate the virus.

Sequence comparisons of the CPV-2 strains obtained in this study showed nucleotide identities of 98.8-100% and amino acid identities of 98-100%. Two nucleotide CPV-2 sequences from different villages and years (H503 from Merenga in 2008 and H506 from Kitawasi (2005) were identical and a third sequence (H469 from Merenga (2008) was translated into the same amino acid sequence.

A blast search identified similar and identical CPV-2 sequences in different continents. A nucleotide sequence described in a dog in Italy in 2005 (accession Nº FJ222824) was found to be identical to sequences H503/H506 and to the Novibac®Puppy DP vaccine strain described in Ecuador (MG264079). This is the same vaccine that has been used in mass dog vaccination programs in the Serengeti ecosystem. It was not reported whether the isolate from Italy was collected from a vaccinated or unvaccinated dog. Other sequences containing one of the two patented vaccine strain mutations (I219V and Q386K) were obtained from foxes and raccoons in China in 2009 (Zhang et Yang, unpublished work, 2010, GenBank® accession Nº GU392236 - GU392241) and from a dog in the USA in 1995 (U22186). All showed a nucleotide identity of 99.8% and amino acid identity of 99.5% with the sequence H503/H506.

Sequence comparisons of the CPV-2a strains obtained in this study showed nucleotide identities of 98.6-99.5% and amino acid identities of 97.8-99.5%. When the CPV-2a isolate H501 from this study was compared with two similar strains found in GenBank®(from a dog in Italy in 2000 (Accession NºAF306445) and a dog in Thailand in 2004 (Accession NºFJ869128), maximum nucleotide identities of 99.8% and 99.6% were obtained and a maximum amino acid identity of 100%. Consequently, the H501 isolate from this study was more similar to the isolates found in Thailand and Italy than with the other two CPV-2a isolates found in Tanzania.

Phylogenetic analysis suggests that CPV-2a sequences from this study are closely related with global strains, suggesting that CPV-2a sequences from the Serengeti ecosystem do not form a clear geographic cluster and are closely related to sequences isolated in other continents. Therefore, in contrast to the FPV sequences in wildlife which displayed a localized geographic clustering, the CPV sequences isolated in this study seem to share a common evolutionary process with global sequences. The CPV-2 sequences isolated in this study clustered with two sequences from Italy and China and the Novibac® Puppy DP vaccine strain (GenBank® accessin number MG264079).

DISCUSSION

We have demonstrated Carnivore parvoviruses to be widely distributed among wild and domestic carnivores in the Serengeti ecosystem. While wildlife was infected with FPV, domestic dogs living around the periphery of the SNP were infected with CPV. With the exception of a jackal infected with CPV-2a, there was no evidence of cross-species transmission, suggesting the existence of two separate epidemiological systems. Given that CPV has been shown to be present in 'wilderness' areas in other continents and that cross-species parvovirus transmission has been documented between domestic and captive and free-living wild carnivores(Steinel *et al*., 2001), this finding was unexpected.

Viral populations in wildlife

We found parvovirus DNA in 13.2% of the wild carnivores sampled in the Serengeti ecosystem. The samples were collected through a convenient non-random method and most were collected from animals found dead on the primary road traversing the center of the SNP. As such, this is not likely to be a representative sample and does not provide an unbiased prevalence estimate. However, because the percentage of wildlife samples found to be positive did not change significantly across the ten years studied or across the species tested, this lends weight to the hypothesis that Carnivore parvoviruses are endemic in wildlife species in the Serengeti ecosystem, as may be the case for wildlife in other continents (Steinel *et al*., 2001). The likelihood of positives was not related to proximity to human habitation, which would be consistent with independent routes of Carnivore parvovirus transmission in wild and domestic carnivores.

Thirteen wild animal samples were found to be positive for Carnivore parvovirus DNA, of which12 were identified as FPV and one as CPV-2a (detected in a black backed jackal). Important amongst these results was the detection for the first time of FPV infection in wild dogs, jackals and hyaenas. Whilst many species of Carnivora appear to be susceptible to Carnivore parvoviruses, the host range of FPV has been reported to be restricted to foxes, felids and some closely related families such as mustelids(Steinel *et al*., 2001). As such, these findings are notable.

In addition, these findings are of interest as they raise questions concerning the interpretation of previous serological studies, which assumed infection with CPV was responsible for seropositive resultsin jackals, hyenas and African wild dogs(Steinel *et al*., 2001). Our results suggest that seropositivity in these earlier studies might have resulted from FPV infection instead, highlighting the importance of strain characterization in understanding Carnivore parvovirus dynamics.

Host susceptibility to Carnivore parvovirus infection is largely driven by the ability of viruses to bind to the carnivore transferrin receptor (TfR) used in host cell attachment (Parker *et al*., 2001; Hueffer *et al*., 2003). Indeed, both FPV and CPV can infect felines because they can bind feline TfR. However, a mutation introduced less than six million years ago into the TfR gene encoding the N-linked glycosylation site in the apical domain confers resistance to FPV infection in most canine species. This glycan mutationis present in coyotes (Canis latrans), wolves (Canis lupus) and domestic dogs (Parker *et al*., 2001; Hueffer *et al*., 2003; Kaelber et al., 2012), but has been shown to be lackingin red foxes, bat eared foxes and black-backed jackals (Kaelber *et al.*, 2012). As predicted by the lack of the glycan-introducing mutation, we report for the first time natural FPV infection in a jackal (H418). Furthermore, we report for the first time that hyena and African wild dog can also be infected by FPV, suggesting these species might also lack the glycan-introducing mutation. This is consistent with the evolutionary history of hyenas, wild dogs and jackals, which all share a relatively distant common ancestor withwolves, coyotes and dogs (Martínez-Navarro & Rook, 2003). It is possible, therefore, that these species diverged before the emergence of the canid glycan-introducing mutation.

Cross-species transmission events of FPV among wildlife species have been previously documented in wild (Steinel *et al*., 2001) and in captive conditions (Duarte *et al*., 2013), suggesting that parvoviruses are transmitted between hosts during contact, for example predation and/or scavenging of carcasses. The finding in this study of genetically indistinguishable viruses in sympatric species in the Serengeti ecosystem provides further evidence that FPV can be transmitted between species and that these transmission events occur in this ecosystem. Even where sequence mutations were identified, phylogenetic analysis demonstrated a close relationship among all the sequences described. This clustering is due primarily to two specific mutations (F303Y and I101T) that characterize all identified Serengeti ecosystem strains. The clustering of Serengeti FPV sequences independently of other sequences reported in GenBank® and the stable number of infections across the ten year period studied also suggests that FPV has been present in this ecosystem for a long time and may be endemic.

It is noteworthy that, of all wild carnivore species tested, we only detected CPVin one species, a jackal. This is in contrast with reports describing CPV infection in wild carnivores in other parts of the world (Steinel *et al.*, 2001). Although the Serengeti ecosystem is considered a relatively intact wilderness, there are populations of humans and domestic animals, including many dogs, living around its periphery and incursions frequently occur (Holdo *et al*., 2009). As a result, it seems likely that wild carnivores would be exposed to CPV in the Serengeti. The lack of detection of CPV in wild carnivores in the Serengeti could arise because wild carnivores are resistant to infection (possibly as a result of FPV within the Serengeti ecosystem creating an immunological barrier), or have been clearing infection, or have been dying in small and imperceptible epidemic waves. This latter explanation seems possible given that most parvoviruses causing disease in large cats have been described not as FPV but as CPV (Steinel *et al.*, 2001). Indeed, a recent analysis of long-term serological data to investigate the transmission ecology of CPV in the Serengeti ecosystem indicates that infection cycles in lions are coupled with those in dogs, providing some evidence of cross-species transmission (Behdenna *et al*., 2019).

However, as CPV and FPV are antigenically similar and difficult to distinguish serologically, it is likely seropositive lions were infected with FPV, complicating the interpretation of the serological data. While the genetic analyses provide no evidence for cross-species transmission, the different conclusions drawn by the serological and genetic studies are not mutually exclusive. Our study suggests that it is likely that FPV is circulating as an endemic infection in lions, however it is also possible that transient outbreaks of CPV may also occur as a result of spill-over from domestic dogs. The integration of data from multiple sources and from more comprehensive sampling will be needed to allow a more complete understanding of a complex epidemiological picture.

The detection of Carnivore parvovirus DNA in a range of tissues supports the hypothesis that, similar to human parvoviruses, Carnivore parvovirus DNA remains in the body following initial infection, as has been shown in previous studies (Allison *et al.*, 2014). These results further highlight the potential value for carnivore parvovirus epidemiological research of tissue samples collected from carcasses and should encourage analysis of such samples collected from other ecosystems across Africa and elsewhere.

Viral populations in dogs and vaccine shedding

With just under half of the domestic dog blood samples being positive, the results indicated that CPV has been circulating widely in the villages adjacent to SNP during 10 years, suggestive of endemicity. This finding was unexpected given that all of the sampled dogs appeared healthy. Our results suggest that CPV

DNA persists in blood for longer periods than thought (Decaro & Buonavoglia, 2012) with no clinical signs.

Surprisingly, 65% of the sequenced viruses from dogs were CPV-2, even though this strain has been replaced in most areas of the world by the newer antigenic types 2a, 2b and, more recently, 2c (Lin & Chiang 2016). The detection of this strain in several different villages over a four-year period generates confidence in this finding. Several lines of evidence suggest that a modified-live vaccine virus was the source of this CPV-2 strain and, because all the samples used in this study belonged to unvaccinated individuals, transmission from vaccinated to unvaccinated dogs may have occurred. First, all the CPV-2 sequences described contained two genetic markers patented by the vaccine manufacturer and artificially introduced to attenuate the vaccine virus (Spibey & Keynes, 2015). Second, three amino acid sequences were identical to the vaccine strain. Third, this vaccine has been used in annual mass dog vaccination programs in the region. Consequently, we conclude that these findings represent cases of natural transmission of vaccine-derived CPV-2 (vdCPV) in domestic dogs. This is the first time that this has been demonstrated empirically.

Although this phenomenon has not been demonstrated before, the potential for this event and the route of transmission has been reported by previous studies. Two studies demonstrated that 23% of dogs immunized against CPV using a modified-live virus vaccine shed virus DNA in their feces during at least 20 days (Truyen *et al*., 1998a; Freisl *et al.*, 2017). A third experimental study demonstrated that, following contact with vaccinated dogs, unvaccinated dogs became seropositive without showing signs of disease (Carmichael et al., 1984). Consequently, it is possible that, following transmission of virus from vaccinated individuals, naive dogs are becoming infected. It is also possible that these infections might result in a protective immunity against CPV.

Although we did not find evidence of cross-species transmission of vdCPV in the Serengeti ecosystem, the host range might not be restricted to domestic dogs. Indeed,the same artificial mutations have been reported in samples obtained from foxes and raccoons from China in2009 (Zhang & Yang, unpublished work, GenBank® accession Nº GU392236 - GU392241), suggesting that vdCPV could be transmitted to wild carnivores. However, because we do not know which brand of vaccine was used in China, we are not able to draw conclusions regarding whether vaccine transmission resulted following vaccination with Nobivac Puppy DP vaccine or if it can be triggered by use of other modified-live parvovirus vaccines.

A concern of live vaccine viruses is the potential for reversion to virulence, although there are no reports in the literature of this happening with vdCPV. Because recombination or novel mutations might lead to a loss of the benign phenotype, surveillance to monitor for such an eventuality would have merit (Shimizu *et al*., 2004).

The circulation of vaccine-derived strains CPV-2a, CPV-2b and CPV-2c would be of more concern than the CPV-2 strain because it has been shown that field strains 2a, 2b and 2c are able to cause disease in felids and in other wildlife species (Steinel *et al*., 2001). For this reason, vaccine shedding from CPV-2a, 2b and 2c live vaccines could have an impact on wild carnivores and we recommend further investigation to assess the risks of the use of these vaccines in proximity to wildlife protected areas.

Intermediate features

Two sequences from this study showed coding mutations at strain-determinant positions. Intermediate features between FPV and CPV have been described only once in a wild carnivore (a red fox from Germany (Truyen *et al.*, 1998b), and intermediate mutations between different CPV strains have been previously described in raccoons (Allison *et al.*, 2014), probably as a result of host-adaptation.

The first, a vdCPV from domestic dog H493 sampled in 2009, hadt he amino acid substitution I101T, common to the CPV-2a strain and to the FPV strains detected in the Serengeti ecosystem. Position 101 is variable and this mutation has been previously described in raccoons and domestic cats (Decaro & Buonavoglia, 2012; Allison *et al*., 2014), however this is the first time an intermediate CPV/CPV-2a strain has been reported in dogs. Although it is not clear whether this substitution arose after a recombination or a mutation event, an evolving modified-live virusis of concern.

The second intermediate mutation was described in the black backed jackal sequence H398 in 2011. Although we classified this strain as CPV-2a, it presented an Asp replacing an Asn residue at amino acid position 323, which is typical of the FPV strain(Lin & Chiang, 2016). Amino acid position 323 is located on a raised region of the capsid surrounding the three-fold spike which contacts the TfR (Hueffer *et al*., 2003). Although this mutation is predicted to reduce replication in canine cells, it is possible that this viral mutation would favor the binding to a feline transferr in receptor present in jackals (Kaelber *et al*., 2012).

In summary, this study has demonstrated that, whilst Carnivore parvovirus infection occurs in numerous species living in the Serengeti ecosystem, there appears to be separated transmission routes involving wild and domestic carnivores. Further more, whilst FPV appears endemic inwild carnivore populations living in the Serengeti ecosystem (including canids and hyenas), CPV-2 and CPV-2a appear to be circulating almost exclusively in domestic dog populations, with CPV-2 infection likely arising as a result of vaccine shedding.

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BUSINESS MODEL: THE ARCHITECTURE TO COMMERCIALIZE BEEKEEPING ACTIVITIES IN TANZANIA

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ABSTRACT

How is a beekeeping industry commercialized and governed in Tanzania? Innovation and businesses are commercialized through business models. Business models are considered to serve to commercialize innovations, as they allow firms to deliver the value of product innovation to their customers at a profit. The model focuses on the ability to explain how a firm makes money: It represents the architecture of the value creation, delivery, and capture mechanisms. Despite increasing investments in the beekeeping sector in Tanzania, the potential for its commercialization is not yet fully utilized. Several factors have been indicated as being responsible for this shortfall, but the commercial structure seems to be most important. This qualitative descriptive study indicates how the business model structure can be used to commercialize beekeeping in Tanzania. A qualitative literature review approach covering business models, business model innovation, and beekeeping structures were reviewed. Content analysis approach was used to analyse business model to point out potential factors and building blocks that can be used to build an effective model. In the end, a beekeeping business model structure was suggested. Five business models were analysed: cooperative, tripartite, collection centre, warehouse receipt system, and contract farming. However, to commercialize the beekeeping sector in Tanzania a partnership design is proposed. Beekeeping in Tanzania is still operating through informal structures. However, one of the important aspects to commercialize beekeeping can be realized through an appropriate business model. The study provides information on the important step to take to build a viable and commercial beekeeping business model. It also provides a theoretical building block for business model innovation in the beekeeping sector.

Keywords: beekeeping, commercial beekeeping, business model, Tanzania

INTRODUCTION

Business models have emerged as an important means of commercializing businesses. It is argued to provide the framework for a firm to create and capture value out of an innovative idea or technological development (Chesbrough, 2010; Teece, 2010; Vanhaverbeke, 2017). An innovative idea does not represent any value until it is commercialized via a business model. Similarly, technological development has no value unless it is commercialized (Schneider & Spieth, 2013). Therefore, business models have been considered as a focus on innovation (Vanhaverbeke, 2017). Business models are acknowledged as important drivers of business commercialization without which value created from innovation cannot be captured. Beekeeping business is no exception and its innovation and technological development requires a business model to be commercial.

Beekeeping includes the art of managing honey bees for the purpose of tapping into their benefits (Cadwallader *et al.*, 2011; Tutuba & Vanhavebeke, 2018). These benefits include food and medicinal, raw materials for industries, and biodiversity protection. Moreover, the management of bee colonies for pollination purposes is increasingly important in effective agriculture (Mwakatobe & Mligwa, 2004; FAO, 2012; Mujuni *et al*., 2012). This presents an opportunity for beekeeping commercialization.

Tanzania is among the countries in the world with the highest potential for production of bee products and it has been practicing beekeeping and honey-hunting for many generations (Mwakatobe & Mligwa, 2006; Tutuba & Vanhaverbeke, 2018). However, the activity has remained local, and non-commercial despite the available potential, high value of beekeeping products (Belgium Technical Cooperation-BTC, 2013) and recognized social, environmental, and economic benefits. This is mainly due to the lack of strong institutions (Msamula *et al.*, 2018) and a proper business model."The beekeeping sector in Tanzaniais still a virgin industry for rewarding investment. There is no organized marketing system to encourage development and expansion of the industry" (International Trade Centre-ITC, 2015). In this regard, to analyse the business model structures in the Tanzanian beekeeping sector is inevitable in order to create, deliver, and capture values in the beekeeping ecosystem.

In this study first, we conceptualize the study concepts to set a theoretical review of the business model and how it can be structured. Second we identify the business model structures available in Tanzanian beekeeping sector. This gives an opportunity to focus on and explain one issue at a time. Finally, we conclude this study by suggesting the business model for beekeeping commercialization. Areas for further studies are also identified and presented.

STUDY CONCEPTS

Beekeeping and Commercial Beekeeping

Beekeeping, also known as apiculture, is defined in various ways (Cadwallader *et al.*, 2011; Guyo & Solomon, 2015). But all definitions point to the art of managing honeybees sustainability for the purpose of tapping into the resource benefits (Tutuba & Vanhaverbeke, 2018; Tutuba *et al*., 2019). Beekeeping is more than collecting and retaining bees in a hive and apiary, or putting a hive in an apiary and waiting to benefit from the bee colony. Beekeeping involves effectively and sustainably managing the bee colony. This requires modern types of equipment and tools, applying appropriate beekeeping knowledge and skills, and accessing potential and profitable markets.

In emerging economies like Tanzania, beekeeping is basically a traditional,local honey hunting, and rural-based activity. It is practiced by local communities, mostly women and the elderly (Mwakatobe & Mligwa, 2006; Mujuni *et al*., 2012; Nyatsande *et al.*,2014; Tutuba *et al.,* 2019). Similarly, unlike other rural economic activities such as agriculture, beekeeping is typically given little attention (Match Maker Associates [MMA], 2012) when it comes to resource allocation and activity development. It is then practiced through local means by those with limited beekeeping knowledge and skills. Therefore, the management of hives, bee colonies, and access to potential markets becomes the most critical challenge in business commercialization.

On the contrary, in developed economies, beekeeping is not only about collecting and retaining bees in a hive and apiary; it involves effectively and sustainably managing the bee colony. This requires modern types of equipment and tools, applying appropriate beekeeping knowledge and skills, and accessing profitable markets. This is what is referred to as modern or commercial beekeeping (Tutuba & Vanhvaerbeke, 2018).Therefore, commercial beekeeping is the application of improved top bar hives and modern types of beekeeping equipment and tools to effectively and sustainably tap into bee colony benefits. However, these benefits can be captured if all potential actors or stakeholders are included in a well-structured business ecosystem. "It is the business model that determines the economic value of a new technology by indicating how customer value is created and how the company can capture part of that value" (Vanhaverbeke, 2017). This raises the need to re-define and review the business model structures of the beekeeping sector in Tanzania. This study, therefore, is set to analyse beekeeping business models available in Tanzania, and define the ways in which beekeeping can be structured to create value to customers and capture value to all potential firms in the business ecosystem.

Beekeeping Commercialization in Tanzania

Beekeeping and honey-hunting have informally been practiced for many generations in Tanzania, so as the way to create, deliver, and capture value from the activity. In 1949, the British colonial government formed a department responsible for beekeeping within the Ministry of Agriculture. In 1998, a national beekeeping policy (NBP) was formulated. Responsibility for beekeeping was transferred to the Ministry of Natural Resources and Tourism (MNRT), within the forests and beekeeping department (United Republic of Tanzania [URT], 1998). The implementation of the NBP was backed by the 2002 Beekeeping Act and a ten-year national beekeeping programme (MNRT, 2001). Furthermore, several projects (MMA, 2007; BTC, 2007; BTC, 2013) and programs (NMRT, 2004)were implemented. Also, different institutions were established to promote, coordinate, and manage the forest and beekeeping resources (Msamula *et al*., 2018). These efforts were intended to professionalize the sector, promote natural forest resources, increase productivity and export earnings from honeybee products and, further, to sustainably contribute to socio-economic development and environmental conservation (URT, 1998; SNV, 2009).

Tanzania is the second-largest honey producer in Africa, after Ethiopia (Nyatsande *et al*., 2014). It is endowed with a favourable environment and multi-flora vegetation,which is ideal for beekeeping (URT, 1998; Pinda, 2014). But this opportunity has not been fully utilized because the sector lacks a strong business model and well-governed value chain."The beekeeping sector in Tanzania is still a virgin industry for rewarding investment. But there is no organized marketing system for both local and foreign markets to encourage the development and expansion of the industry"(ITC, 2015).Moreover, emerging and rural markets, which are also termed "low-income markets" (Prahalad & Hart, 2002; Sanchez & Joan, 2010; Prahalad, 2012), has unique characteristics that present an excellent business growth opportunity. These characteristics include market size, competitiveness, and opportunities for innovation (Majumder, 2012; Chikweche, 2013; Tutuba *et al*., 2019). Furthermore, as Tanzania aspires to be a middle-income economy through industrialization (URT, 2016), the beekeeping sector provides an opportunity to be a potential source of industrial raw material. However, these opportunities cannot be browbeaten without an efficient business model: "… the logic of value creation in low-income markets depends on the nature of the business model"

(Sanchez & Joan, 2010). Therefore, using modern beekeeping types of equipment and tools, techniques, knowledge, and skills will improve productivity and quality of the hive products. The development of good business model structures, thus, coordinates all these activities toward beekeeping market potentials. A well-structured business model ensures sustainability and profitability to all actors of the beekeeping ecosystem. Consequently, an innovative business model is inevitable in order to reachto the beekeeping commercialization potential available in Tanzania.

Business Model

The term "business model" is often used but is not clearly defined (Chesbrough, 2007). It is often studied without an explicit conceptualization (Zott *et al.*, 2011). "Despite the fact that the term 'business model' is used widely in the business world, academic research is relatively sparse, and there is no consensus because researchers define business models in different ways" (Vanhaverbeke *et al*., 2012). Therefore, it is important to have a common understanding of the concept to silhouette the study.

Lindgardt *et al.* (2009) and Chesbrough (2007, 2010) defined a business model based on six functional parameters that might generate new value in an industry. However, they all focus on how firms create (value proposition) and capture (operating model) value. A business model articulates the logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value (Teece, 2010). Amit & Zott(2014) defined a business model as a system that is designed and enabled by a local firm in order to meet perceived market needs. A business model defines the way companies create and deliver value to a set of customers at a profit (Vanhaverbeke *et al*., 2012; Vanhaverbeke, 2017; Tutuba *et al*., 2019). Furthermore, Osterwalder and Pigneur(2010) define a business model as a description of the rationale of how an organization creates, delivers, and captures value. Schneider & Spieth (2013) defined it as the heuristic logic that connects technical potential with the realization of economic value. In this regard, a business model can be defined as a statement, a description, a representation, architecture, a conceptual tool or model, a structural template, a method, a framework, a pattern,relation function, and a set of activities that define how profits are made. Business model is the way through which value is created, delivered or channeled to customers, and in the end value is captured for all participating firms or organizations in the value system. Basically, the business model is the how of doing business. Following this understanding of the business model, its theoretical understanding has been contained by the necessity to comprehend new ways of earning money (Schneider & Spieth, 2013). The focus has been on explaining the business ecosystem's ability to work profitably. This raised attempts to refer to the term as the representation of the architecture of the value creation, delivery, and capture mechanisms (Osterwalder & Pigneur, 2010). Similarly, the literature covering the elements and the process of conducting business model innovation has experienced a strong emphasis. Different works of literature, as summarized in Table 1,suggests business model architecture on its capacity to integrate the focal firm's ecosystem.

Table 1: Description of Business Model Building Blocks

Author	Business Model Building Blocks	Core Focuses
Chesbrough (2007)	• Value proposition • Target market • Value chain • Revenue mechanisms • Value network or ecosystem • Competitive strategy	• Value creation: a series of activities, from raw materials to consumption. • Value capture: Profits made from a series of activities that created value.
Lindgardt *et al*. (2009)	• Target segment • Product or service offering • Revenue model • Value chain • Cost model • Organization	• Value proposition • Operating model
Chesbrough (2010)	• Articulate the value proposition • Identify a market segment and specify the revenue generation mechanism • Define the structure of the value chain and paired assets needed to support position in the chain • Details the revenue mechanism(s) • Estimate the cost structure and profit potential • Describe the position of the firm within the value network • Formulate the competitive strategy	A business model is confined to six basic functions of creating and capturing value in the business ecosystem
Osterwalder & Pigneur (2010)	• Customer segments • Value proposition • Channels • Customer relationships • Key resources • Key activities • Key partnerships • Revenue streams • Cost structure	• Customer/value stream • Firm/organization operation stream • Profit/value capture stream

Vanhaverbeke *et al.* (2012)	Identify a specific customers group to serve Create a customer value proposition Identify key resources Identify key processes needed to deliver that value Design a profit formula	
Amit & Zott (2012)	• What customer needs will the new business model address? • What novel activities could help satisfy those needs? • How could the activities be linked in novel ways? • Who should perform the activities? • What novel can governance arrangements be found? • • How will the value be created for each stakeholder? • What revenue models can be adapted to complement the business model?	• Content (selection of activities to be performed) • Structure (how the activities are linked and in what sequence?) and Governance (who performs the activities?)
Masanell & Feng (2013)	How it creates value for customers How it captures value for its stakeholders	The business model is built along a simple profit function

Source: Review of different kinds of literature

Chesbrough (2010) points out the formulation of a competitive strategy as one of the focus functions of a business model, along with governance and structure building elements. However, a business model is conceptually different from an organizational structure, product-market positioning strategy (Amit & Zott, 2014) or a value chain proposition. Although, it must be considered as a fundamental aspect of a firm's overall strategy. Therefore, at a theoretical level, a business model [innovation] is the process of designing/modifying a firm's extant activity system or as the discovery of a fundamentally different business model in an existing business (Schneider & Spieth, 2013).

At its heart, a business model should be built to perform two important functions: revenue/value creation and value capture. First, it creates net value through a defined series of activities, from raw materials acquisition to consumer satisfaction. This is important because, if there is no net creation of value, the other companies involved in an ecosystem won't participate. Second, it captures value from a portion of those activities. This is equally important because an unprofitable business is not sustainable. According to this understanding, despite the overlapping of building blocks, business model architecture is cantered on the value proposition. A business model demonstrates how an ecosystem creates, delivers, and captures value. "Business model defines the way businesses deliver value to a set of customers at a profit as it involves linking elements: companies create a customer value proposition, identify key resources and processes needed to deliver that value, and design a profit formula" (Vanhaverbeke *et al.*, 2012)

To experiment with alternative business models, one promising approach is to construct maps of business models, to clarify the processes underlying them, which then allows them to become a source of experiments considering alternate combinations of the processes (Chesbrough, 2010). This modelling approach provides a pro-active way to experiment with different business architectures, and allow organizations to try various possibilities before committing to a specific model. Therefore, theoretical considerations of configuring elements of a business model here can become far more concrete as shown in figure 1 below.

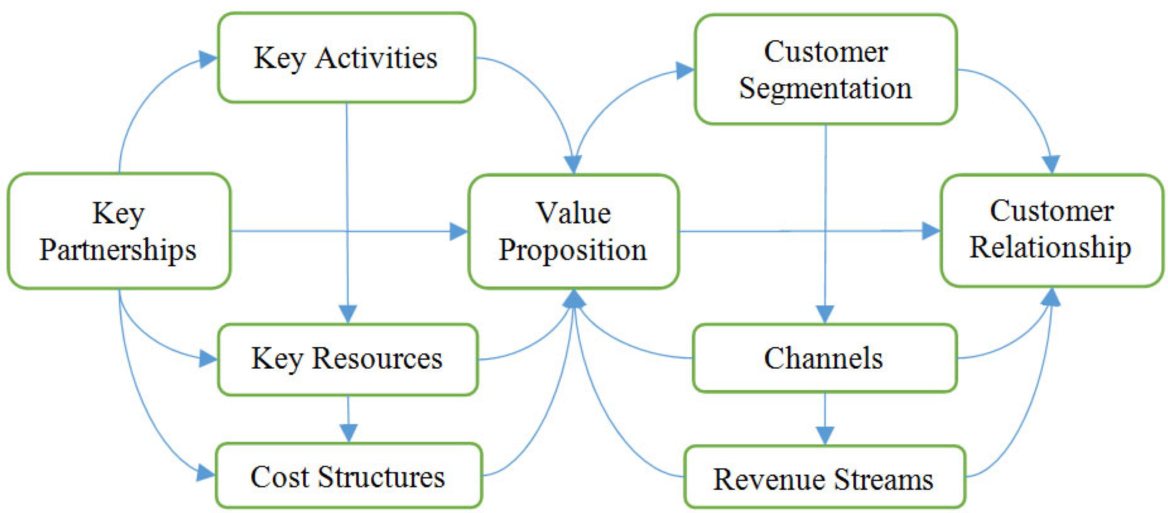

Fig. 1. Elements of a business model structure. (Source: Chesbrough, 2010; Osterwalder & Pigneur, 2010).

Partnership Business model

The partnership model is structured around the connection of partners in the value delivery process. Four building blocks are designed to make sure that value is captured as it can be created by all partners in the business. Figure 2 below shows the partnership model for commercialization of beekeeping activities.

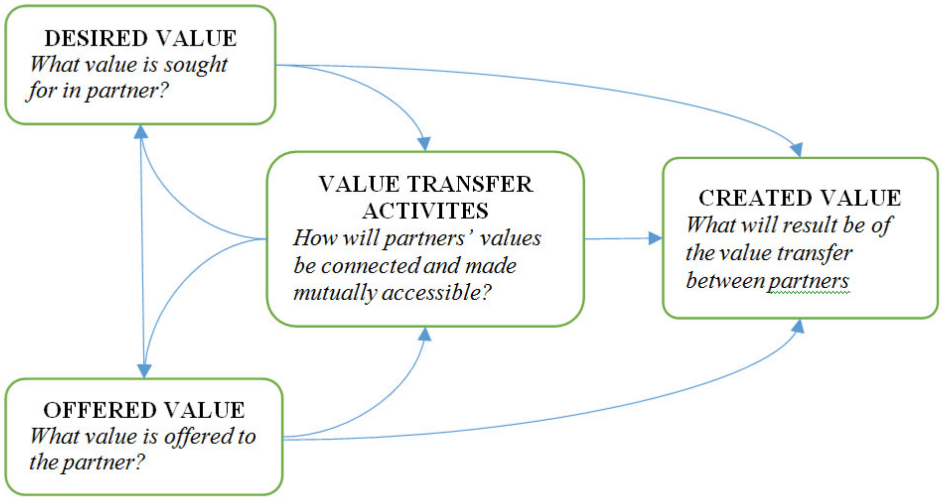

Fig. 2. The Partnership Business Model Structure (Source: Adapted from https://valuechaingeneration.com/2014/10/17/the-partnership-canvas/ as visited on March 10, 2018.

The desired value is the building block aiming to look for a partners' contribution in the model: what value is sought for a partner? Why do we need a partner? What value do partner convey in the business? To fill in this block, the firm describes the missing component from its own business model, for which it finds a partner. For example, if aggregation and processing are missing elements, then, firm will look for a partner to cover those components. The description of the missing components are used to screen candidate partners on value(s) it desire.

APPROACH AND METHODOLOGY

Expanding interest in business models and business model innovation has led to an increasingly wide and confusing body of literature (Schneider& Spieth, 2013). We adopted the three-stage process for systematic literature reviews suggested by Tanfield *et al.* (2003). In order to gain an overview of the existing literature on the business model in beekeeping sector, we first identified our research objective and designed our literature review process accordingly. Second, we conceptualized the terms "business model" and "business model innovation." This required careful screening of the articles in order to select those that focus on the innovation of established business models. Lastly, we analysed business model structures in the view of commercialization of the beekeeping sector.

In analysing a sample of research documents in a systematic and rule-governed way content analysis was used. . It is a research technique for a systematic and quantitative description of the manifest content of the communication and includes any methodological measurement applied to text (or other symbolic materials) for social science purposes (Seuring & Gold, 2012). Therefore, four main steps forming the process model of (qualitative) content analysis was adopted (Seuring & Gold, 2012; Schneider& Spieth, 2013): first, the material to be analysed is delimitated, and the unit of analysis is defined (material collection). Second, formal characteristics of the material being assessed, providing the background for subsequent content analysis (descriptive analysis). Third, the structural dimensions and related analytic categories are selected, which are to be applied to the collected material (category selection); last, the material is analysed according to the (analytic) dimensions (material evaluation).

To report our findings within the third step of the process, existing literature on business model innovation, we presented different models used in beekeeping commercialization in Tanzania. Within each model, extant contributions are discussed focusing on how the model creates net value for the beekeeping ecosystem.

Business Models in the Beekeeping Sector in Tanzania

In spite of every business model being unique, there are general models that can be used as guidelines. But in Tanzania, a business model for commercial beekeeping is not yet in place (MMA, 2007; MNRT, 2004). However, different models have been designed and piloted without full adoption.

Therefore, this section analyses different business models in two parts: first, by analysing the nature of the interdependencies developed by the business,i.e., to analyse the impact of the business model on the ecosystem; second, to critically observe its applicability in the Tanzanian beekeeping sector toward commercialization.

Cooperative Business Model

The cooperative structure is among the highly suggested and preferred business models by the government and developing partners (Institute of Community and Organizational Development-CODIT, 2009; Sizya, 2001). The model is highly preferred because of its advantages, most of which provide a solution to most of the rural business operation challenges. Some of the advantages are shared resources, experience and skills, aggregation, and gaining bargaining powers.

The operation structure of the cooperative business model is structured around a cooperative (MMA, 2007; Cadwallader et al., 2011). However, there are different modes of cooperatives to include: community-based enterprises/organizations (CBO), regional, national, and crop/produce-based cooperatives. During the study, we found that most beekeeping cooperatives and associations are available to a few regions, which include Tabora, Kibondo, Arusha,and Dodoma.At the national level, the Tanzania Beekeepers Association and Tanzania Honey Council are the most effective beekeeping associations. However, most regional associations are weak, fragmented, and are not pushing the beekeeping development agenda due to limited capacity, focus, and resources.

Another challenge to this model is based on the lost faith in the ability of cooperatives to help rural people overcome their problems. Sizya (2001) points out that the brief review of cooperative development in Tanzania during the last six decades suggests that little seems to have taken place among the rural communities, where the cooperatives were intended to contribute to better living standards.

The tricky situation of a cooperative model relies on the need for good governance, cooperation, and communication. This sort of business model would logically require a collective of other individual responsibilities among members. This could be achieved through a combination of actions and procedures, e.g., elections, rotations, and permanent responsibilities for members depending on their knowledge, skills, and experience. Other actions are decisions, mutual agreements, and voting, along with constitution guidance. With exclusive responsibilities, however, comes the need for increased dedication as well as honesty. As there is bound to be some sort of conflict, members need to agree upon a method of resolving said conflict.

Tripartite Business Model

In 2000, Honey Care Africa developed a unique business structure that can be applied in the beekeeping sector: the tripartite business model. The model was successfully developed, piloted, and adopted in Kenya (Jiwa, 2000). This business model is configured to operate in a three-way synergistic partnership. The business structure is sketched on the core capabilities of each partner because each partner has a specific and complementary role to play. Therefore, the value is created and captured through a strategic and synergistic partnership of core partners: the development sector organization (DSO), private sector (PSO), and rural community (RC).

The first partner in the structure is the DSO, whose main roles in the model are to facilitate linkage and play an arbitration and mediation role (Branzei & Mike, 2007). This creates a check and balance between the two trading parties. For example, PSO cannot develop the exploitative relation to beekeepers, and beekeepers cannot sell to other unrelated PSO. In some cases, DSO provides financial support and facilitates initial business operations. Therefore, DSOs should have a broad outreach and experience in working with RC to make them an ideal waterway for the system.

The second partner in the model is the PSOs. This includes commercial firms of the ecosystem. It is the commercial heart of the system. At all times PSO is sensitive to supply–demand dynamics and plays an important role in ensuring the structure can be commercial. In order to create value for all actors in the beekeeping ecosystem, PSOs have to collect, process, pack and sell honey for profit.

The last partner in this symbiotic model is the RC. This partner includes the beekeepers and honey hunters. Their main role in the model is to effectively and efficiently produce quality products. The value propositions of the model begin here.

Despite the successful commercialization of the beekeeping sector by the tripartite model in Kenya, the experience in Tanzania is different. During the study, we observed that the model is constantly facing operational challenges. The first challenge is over-reliance of the PSO's actions and decisions. Because all key activities are done by PSOs, sustainability and efficiency of the business structure will, therefore, depend on that of the PSO. If it collapses, the whole model will collapse. In the Morogoro district, for example, we observed three beekeeping businesses that collapsed because the PSO ceased operations in the area.

The second challenge is an inability to create value for those established through donor-funded projects, which made them unsustainable. "The huge funding from donors has been disbursed … but insignificant impact on the ground. Many small-scale beekeepers in this country have remained very poor despite numerous interventions to improve the sector"(MMA, 2007).

The third challenge is the conflicting goals and objectives between partners in the model. Their differences are extended to affect the revenue streams and cost structures. For example, PSOs are profit-oriented, while DSOs are mostly charitable and social-oriented. They differently define customers (segmentation), value propositions, channels, and relationships.

Therefore, PSO partners with RC on a profit basis, while DSOs do it is for community outreach. It is important for partners to have common objectives so that they can mutually create and capture value for every member of the beekeeping ecosystem.

Another important observation is the failure of DSOs to play a coordination role between other operating units. When this happens, the model looks like a duopartite than tripartite. For example, when there is a missing link between DSO and RC, PSO have to resolve rising conflicts between them. "There was one member who was not being cooperative. He was thinking of selling his honey somewhere else. We talked to him, and now he's all right" (Branzei & Mike, 2007).

The fair inclusion of beekeeping community members is challenging. It may rise into division and jealousy among beekeepers,which reduces the future performance of the model. In the Mvomero district, for example, we observed a conflict between two beekeeping groups just because one group was supported by DSOs. Therefore, for the model to create value, it needs a fair synergistic inclusion of all potential partners of the ecosystem.

The tripartite model creates a favourable condition to start beekeeping through a combination of different partners. It also shows inclusion of other key partners, DSOs, which may not be directly linked to core business activities. These partners have to ensure support for adequate training and easy access to beekeeping tools and equipment. Also, easy payment, a guaranteed market at a mutually acceptable price, and cashon-the-spot payment are the most important issues of the model. However, a different and more sustainable beekeeping business model is necessary to make sure the beekeeping sector is commercialized.

Collection Centre Model

The collection centre model is a business model in which all commercialization activities are structured around a collection point known as a collection centre. The centre is used for aggregation purposes. Beekeepers bring their products to the collection centre. Buyers collect the product from the centre.

Depending on how it is owned and managed, the model is structured/formulated around the collection centre to perform the aggregation, commercialization, and linkage roles. It receives products from depositors (beekeepers), checks for quality, traceability, and does the grading. It manages deposits, keeps records, maintains safety, and find markets. Also, it is a link between producers (beekeepers) and buyers or private sector organizations.

A well-structured collection centre creates a good link such that products are easily sold and at a good price. However, developing an appropriate commercial structure is a challenge, particularly in establishing the cost structures. Africare and BTC are still piloting the model in Tabora and Kigoma regions, respectively (MMA, 2007; BTC, 2013).

The strength of the model, however, is built on its ability to manage the revenue streams. With well-defined activities of the centre: value proposition, customer segments, channels, and relationships can also be well managed. To achieve this, a well-structured partnership model is necessary.

Warehouse Receipt System Model

Warehouse receipt systems (WRS) is one of a series of a modern market model that can be adopted in different combinations and permutations according to the circumstances. It has been used to develop more productive agriculture markets in delivering benefits to producers and consumers (URT, 2012). First, it arranges a market window, which can help to secure the best possible deals. Second, it provides a platform for the introduction of institutional innovation like product grading and exchange trading (Onumah, 2010). Third, it provides a focus for development of the entire commodity chain through incentives. Last, it facilitates aggregation of products (Paschal, 2012; URT, 2012).

The model is structured around a registered warehouse, and it is run or traded by using a transferable document called a "warehouse receipt". To serve its purpose, WRS includes other participants like financial institutions, PSOs, and DSOs. Also, it integrates the government, through its agencies and organs, to oversee the system.

In some cases, the model seems to be inappropriate because of constant government and political interventions. However, we think the inclusion of government agencies is important because operating in unclear rules, regulations, and procedures that govern the sector reduces the ability to capture value. "… government regulations can change a profitable SME niche business into a nightmare in just a few weeks or months"(Vanhaverbeke *et al*., 2012).

Therefore, WRS model in the beekeeping sector can be effective if a key partnership is well structured and coordinated such that there are trust and operational confidence among members. Also, cost structures should be reviewed so that beekeepers can see the benefit of trading through the model.

Contract Farming Business Model

Contract farming (CF) is a forward agreement specifying the obligations of farmers and buyers as partners in business (Will, 2013). Normally, a buyer provides embedded services such as inputs, pre-financing of input delivery on credit, and other non-financial services.

Melese (2011) described CF as one such structure offering opportunities to agribusinesses to lower transaction costs. They gain a degree of control over the production process and traceability without necessarily requiring ownership. It is one of the governance structures between the two extremes: spot market and vertical integration.

The model can be setup through different business structures,depending on the intensity of vertical coordination, the type of product and inputs engaged, and the number of key partnerships involved in the ecosystem. The model can be grouped into five contract farming structures (Will, 2013; Tutuba *et al*., 2019): the centralized model, nucleus estate model, multipartite model, informal model, and an intermediary.

The centralized modelis the one that PSOs turn into the centre of the ecosystem. They trade with producers under strict predetermined quantity and quality-control conditions. The involvement of PSOs can vary from supporting with the inputs to providing different services and technologies at various stages. The Honey King company, for example, uses this model in Taboa region.

The nucleus estate modelalso referred to as the"out-grower learning farm model," or shamba darasa in Swahili is a variation of the centralized model, where PSOs own an apiary adjacent to independent contracting producers. The estate is usually used to guarantee throughput for the processing unit. Also, it is used for research and breeding purposes. The farmers are at times called "satellite farmers," illustrating their link to the nucleus farm. E.g. Ruaha farms use the model in Iringa region.

The multipartite modelis a business structure that involves various partners such as governments, NGOs, and service providers in the contract. According to different studies (Jiwa, 2000; Melese, 2011; Will, 2013; Msamula *et al.*, 2018; Tutuba *et al*., 2019), this is an appropriate model for rural producers. It integrates the effort of many actors. Therefore, it eases the burden on individual contracting parties. Usually, the model involves producers through their organizations, and it creates a partnership among the government, DSOs, and the PSOs. Contracts under this model may involve a varying degree of coordination depending on the interest they have in an ecosystem. The fourth model is the informal model, which is usually characterized by entrepreneurs and/ or small companies that enter into informal contracts, usually on a seasonal basis. Unlike the first three models, this model has limited resources for strong vertical coordination. Therefore, its success usually depends on the strengths of social bonds among contracting parties, the amount of business and operational support provided in the ecosystem. In Tanzania, this is the most available business structure. Because beekeeping operates under informal arrangements, it also depends on informal business structures. Last is the intermediary model, which involves intermediaries, the agents, between producers and buyers. They act as the link between producers and PSOs. Also, they set business terms and conditions based on the requests of PSOs. However, in most cases, the arrangements are on short-term bases. Creating value in this model depends solely on the performance of intermediaries.

DISCUSSION

In practice, the above-mentioned models are not mutually exclusive. For example, combined features of different contract farming may be found in one contractual arrangement. This is to say that the boundaries between models are fluid with regard to organizational structures, operational arrangements, and size of operations.

The models chosen for starting up a scheme may change over time through the integration of lessons learned, changing attitudes, and adoption of new technologies. A model that proves to be appropriate for the start-up phase, or the certain location, may need to be adapted and perhaps changed for the consolidation and scaling up phase, respectively.

Adopting a beekeeping business model has shown some challenges mostly from the beekeepers' side. Side-selling, adulteration, and aggregation are the most pressing issues for value capture. For example, some beekeepers breach the terms of a contract when other buyers offer a better price than that offered in the contract. They failed to work as per the contract terms with the Honey King, the Chinese honey processing company in Tanzania. Also, beekeepers misuse or resell the provided inputs. In Turiani, Morogoro region some beekeeping groups have started to lease protective equipment.

Similarly, beekeepers are disadvantaged in some situations. For example, whenever the market condition changes, produce may be rejected and prices re-negotiated on the grounds of quality conformity. Moreover, non-transparent pricing mechanisms, quality specifications, and loss of control and flexibility in deciding production mixcan limit beekeepers to benefit from market opportunities. Therefore, an innovative model is needed to ensure sustainability of value capture for beekeepers. The model should include moderating partners such as the government agencies, DSOs,which can ensure that all partners benefit in the ecosystem.

In Tanzania, it is evident that identifying and selecting beekeeping commercial model is an art rather than scientific process. The sector is washed with many actors who use different approaches and art of conducting business transactions. Beekeepers who are the main producers and the core elements of the business model, are being approached by traders or intermediaries and processors from local and regional markets on a short-term transaction basis. There is hardly a business pattern established after the collapse of Beekeepers Cooperative Societies in the late 1990s (MMA, 2007).

Of late, several support organizations have taken different entry points of supporting the different actors in the chains. It is difficult to identify what may be termed good or best practice in linking beekeepers to markets. Hence, there is no one and the only way to identify and select a value chain as well as business structure to further be promoted. In such a situation, it is not about selecting one of the channels – it might also entail crafting a chain or a combination of chains that would deliver the benefits of well-functioning structures, as discussed above.

Experience has shown that most beekeepers are not operating on business principles, and their participation is not based on economically viable units, as they still use traditional approaches, which are inefficient. Also, the adoption of improved models and their optimal use has not been attained. Keeping in mind the characteristics and key elements of business model innovation, it is important to identify a partnership business model that creates and supports thresholds for the involvement of beekeepers based on economically viable units. It should be a partnership that considers beekeeping as a business and not as a tradition. Involvement of the beekeepers as partners in the model should be judged on the merits of providing an opportunity that outsmarts the alternative use of labour and investment at a household level.

Offered value defines the firms' contribution to the partnership: what value is offered to the partner? What matching offer are we contributing in the business? After recognizing a desired value in a partner, then a matching offer that connects with that value should be developed. An effective offer either complements or adds to the desired value from a partner. Since all partners need to capture value, therefore, unless this connection is made, a basis for creating a relationship is possible. Otherwise, the model will not be ecological.

To minimize the challenges and contradictions observed in the cooperative, tripartite, and contract farming models, it is important for partners to decide on the way to connect values. Through what collaboration activities will value be connected? Through what arrangements will these values be connected? How will desired and offered values be connected? The value transfer activity defines the exchange by which synergy between the partnering business models is created. It is important that partners find a way to integrate the value that they are putting to the table.

Lastly, is the value creation building blocks; basically, the first three blocks define a basis for connecting values. However, the critical question is whether this value engine enables to create a new form of value in one of the business model. Therefore, with the first three building blocks, an engine is created that enables value to flow between partners.

To create net value in emerging markets, there are different strategies. However, creating an ecosystem that co-evolves with inputs from partners, many of them located outside the formal economy, not only helps to improve socio-economic context but also allows value creation and it is a source of a more sustainable competitive advantage. Business models with a high degree of cooperative interdependences are especially convenient for this goal. While it is true that this scenario presents greater uncertainties, we have shown through out this paper different success stories of how firms' efforts and creativity have been fully rewarded.

Conclusion and Study Implication

A good business model should aim to create value for customers and also capture value for participants in the ecosystem. In beekeeping, two factors are important to consider when building a business model: quality of the products and volume. However, it is a challenge to obtain good volume without compromising quality. Beekeepers alone cannot capture this potential, they should collaborate with other organisations with complementary skills and assets to create value and capture value from the activity. The partnership model can take advantage of this opportunity and gain greater efficiencies in its operations. Partners can refine and extends its own skills, capabilities, and resources to commercialize the sector. The expected result, in this case, is an innovative partnership model which is able to increase income options while generating economic profits. Therefore, the benefit to local communities, in this case, goes beyond consumption, since it helps to meet broader social interests of those actors involved in the business model. In short, interactive business models apply new engineering logic for changing the actors' behaviour and creating the capacity to pay.

In sum, there are different strategies when entering the low-income markets. However, creating an ecosystem that co-evolves with inputs from global and local partners, many of them located outside the formal economy, not only helps to improve socio-economic context but also allows value creation and it is a source of a more sustainable competitive advantage. Business models with a high degree of cooperative interdependences are especially convenient for this goal.

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PRELIMINARY RESULTS ON ELEPHANT CONSERVATION THROUGH LOCAL COMMUNITIES PARTICIPATION AROUND THE SERENGETI ECOSYSTEM

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ABSTRACT

Lack of support from local communities for conservation and illegal resource harvest within Protected Areas (PAs) are among the major challenges for sustainable wildlife conservation including elephants. High human population growth rate and density in Africa, escalates Human Elephant Conflicts (HEC) as elephants try to disperse outside PAs where human population density is high. This study assessed participation of local communities towards elephant conservation in the Serengeti Ecosystem (SE). The study was conducted in 12 villages, located in four districts in SE namely; Bariadi, Ngorongoro, Meatu and Serengeti Districts. A questionnaire survey was used for data collections. Out of 446 respondents, 76.2% of the respondents agreed that it is important to conserve elephants and other wildlife. However, nearly half (44.6%) of respondents support and assist conservation of elephants by physical participation in anti-poaching activities with wildlife authorities, informers in uncovering poachers, provision of conservation education to others and adhere to conservation laws. Furthermore, 75.3 % of respondents had experienced HEC during the past five years and crop raiding was reported to be the greatest problem (76%).On the other hand, those who had negative opinions or opposed conservation efforts for elephants had experienced HEC which impacted negatively on their livelihoods or lacked conservation education. We conclude that local communities in the SE are willing to participate and contribute towards elephants' conservation, despite the losses incurred from them. Therefore, this study recommends Management Authorities to provide conservation education to communities surrounding protected areas to enhance community involvement in planning and sharing benefits from wildlife conservation. Also, the use of appropriate mitigation measures to minimize HEC in order to reduce negative perception of local people towards elephant conservation is highly recommended.

Keywords: Human Elephant Conflict, Local Communities, Serengeti Ecosystem.

INTRODUCTION

Biodiversity conservation has become one of the most challenging issues of the 21st century to the planet Earth (Hossen, 2013). The biodiversity on Earth is currently declining, and loss of biodiversity and natural habitats is due to increasing human pressure both outside and inside protected areas (PAs) (URT, 2015). Furthermore, in Africa high human population growth and density as well as extensive conversion of adjacent unprotected landscape for agriculture, escalate Human Elephant Conflicts (HEC) as elephants try to disperse outside PAs where human population density is high (Redpath, *et al*., 2013; Synder *et. al*., 2019). In many third world countries, environmental resources accounts to an average of 28% of the total income of rural household (Angelsen *et al.*, 2014). Rural households use ecosystem services as food, fuel, fodder, construction materials, medicine, and other products from forests and other natural environments to meet their subsistence needs and generate cash income (FAO, 2008).

HEC exists in different forms both in Africa and Asia (Leta *et al*., 2016). It arises with complex interactions between humans and elephants often resulting in detrimental impacts for both humans and elephants in different ways; crop raiding, property damage, injuries and deaths to humans, retaliatory killings and poaching for ivory(Chang'a *et al*., 2016; Hariohay *et al*., 2019). HEC has adverse impacts on people's livelihoods in areas around PAs, leading to reduced support for conservation efforts. Elephants (*Loxodanta africana*) are among the most reported destructive animals in the SE (Walpole *et al*., 2004; Mwakatobe *et al.,* 2014; Synder *et. al.*, 2019) as well as other different parts of Africa and Asia (van de Water & Matteso, 2018; Sampson, *et al*., 2019).

Participation of local communities provide an important means of assessing the performance of conservation projects so that better policies may be developed for effective biodiversity protection and the wellbeing of people living near PAs (Abukari & Mwalyosi, 2020). The impacts of PAs on local livelihoods can be major determinants of attitudes of local communities towards conservation (Clements *et al*., 2014; Nsonsia *et al*., 2017). Effective conservation requires a better understanding of how humans interact with natural resources both inside and outside PAs (Estes *et al*., 2012). Lack of support from local communities for conservation and illegal resource harvest within PAs, are among the major challenges for sustainable biodiversity conservation (Ruckelshaus *et al*., 2013; Sampson *et al*., 2019).

The support of local communities towards elephant conservation can only be improved through implementation of locally-adopted conservation strategies with positive socio-economic impacts to household livelihoods. The present study aimed at investigating the participation of local communities towards elephant conservation around the SE. We hypothesized that local communities around the SE are willing to participate towards sustainable conservation of elephant populations. Also, we hypothesized that the majority of local communities around the SE have experienced HEC.

MATERIALS AND METHODS

Study site

The study was conducted in 12 villages, located in four districts around the Serengeti ecosystem (SE) namely; Bariadi, Ngorongoro, Meatu and Serengeti Districts. SE covers 25,175 km^2 (between 2^{o}16' to 2^{o}83' latitude, and 33^{o}87' to 35.96^o longitude) at an elevation ranging from 900 m to 1,950 m above sea level (Fig. 1). The

Serengeti Mara Ecosystem is one of the six key ecosystems for wildlife conservation in Tanzania (TAWIRI, 2014). A total of 6,087 elephants were counted in SE, suggesting a tremendous increase of 98.4% (3,019 elephants) compared to 3,068 elephants that were counted in a similar survey carried out in 2009 (TAWIRI, 2014). Also, SE is known to support a number of economic activities to local communities surrounding protected areas including tourism (TAWIRI, 2014). Sport hunting is practiced in the adjacent Game Reserves (GRs) and Game Control Areas (GCA). Livestock rearing, charcoal production, agricultural activities, mining, logging and other forms of land use also take place in unprotected parts of the ecosystem (TAWIRI, 2014). SE is a highland savannah region with thorn tree woodlands and plains ranging from approximately 900 to 1,500 metres above sea level. Mean annual rainfall across the ecosystem is ranging from 523 mm to 1236 mm with the northwest side of the ecosystem being the wettest (Metzger *et al.*, 2010). The monthly maximum temperature means in the western Serengeti fluctuate between 25°C to 32°C and the minimum daily temperature ranges between 13°C and 19°C (Campbel & Hofer, 1995).

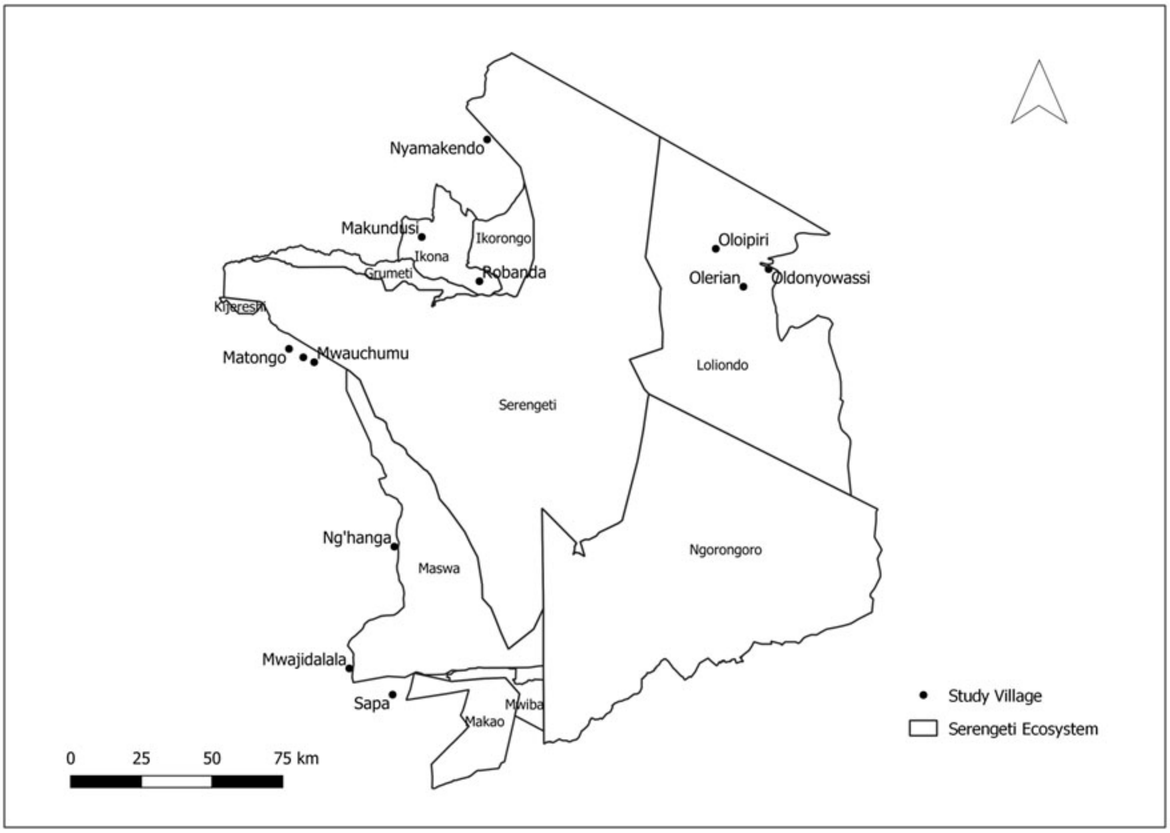

Fig. 1. Map of the Serengeti Ecosystem showing study villages (brown squares)

Data collection

Data were collected using a semi-structured questionnaire from a total of 446 households in the districts of Ngorongoro, Meatu, Bariadi, and Serengeti (Fig. 1). The aspects covered on importance of conserving elephants and other wildlife, included the participation of local communities in different elephant conservation activities, reasons for negative attitudes to elephant conservation efforts, households' experience on HEC during the past five years, types and extent of HEC, suggestions of mitigation strategies towards HEC.

Data analysis

Statistical data analyses were performed using SPSS version 21.0 to generated frequency tests and Chi-square-tests ($\chi 2$) for comparison of the significance of variations in testing our hypotheses. A linear regression analysis model was used to test the significant independent variables in explaining the observed variations in support towards elephant conservation.

RESULTS

Local communities' participation to support elephant conservation

Most of the respondents (76.2%, n=446), agreed that it is important to conserve elephants as well as other wildlife. Nearly half of the respondents (44.6%, n=446) participated in supporting and assisting conservation of elephants through different means; including a) informing about and uncovering poachers (15.9%, n= 446), b) physical participation in anti-poaching activities with the wildlife authority (11.2%), c) provision of conservation education to others (10.5%) and d) adherence to conservation laws (6.9%). On the other hand, 55.4% of the respondents did not participate in any elephant conservation activity.

Using linear regression model three variables were significant in explaining the 25.4% variations observed towards support on elephant conservation in the area; education level, sex of the respondents and district. Other remaining independent variables were not significant, although age was closely related but statistically was not significant (Table 1).In the table we present significant factors from a linear regression model with support on elephant conservation as a dependent variable and six independent variables: village, district, age, sex, tribe and education level. B: Estimate, SE: standard error and P: p-value.

Table 1: Six factors that might predict differences in support towards elephant conservation

	Unstandardized Coefficients		Standardized Coefficients		
Independent Variables	B	SE	Beta	t	P
(Constant)	0.58	0.11		5.50	<0.0001
Education	-0.12	0.04	0.16	-3.24	0.001
Sex	0.11	0.05	-0.12	2.39	0.017
District	-0.07	0.04	-0.16	-1.97	0.050
Age	-0.04	0.02	-0.09	-1.78	0.077
Tribe	0.02	0.02	0.07	1.27	0.204
Village	0.00	0.01	0.01	0.13	0.901

Experience of local communities towards human elephant conflicts

Most of the respondents (75.3%, n = 446) experienced problems with elephants during the past 5 years, while 20.2% did not and 4.5% of the respondents did not answer the question. Crop raiding (76%, n = 446), people injured (0.9%), loss of human life (0.7%), grain store demolished (0.2%), water infrastructures destroyed (0.7%) were the common HECs, while 21.5% of respondents did not report any type of conflict. There was a significant difference between districts in experiencing problems with elephants as most of those who experienced problems were from the Serengeti district, followed by Bariadi, Meatu and Ngorongoro was the least (Table 2).

Table 2: Differences in respondent's experiences of HECsduring the past 5 years versus age, sex and districts

Variable	Category	Experience any problems with elephants in your family during the past 5 years			Statistical test		
		Yes	No	N	χ2	df	P
Age	18-30	72.7	27.3	128	14.57	5	0.471
	31-43	82.4	17.6	131			
	44-56	80.7	19.3	88			
	57-69	78.9	21.1	38			
	70-82	82.1	17.9	28			
	83-95	100.0	0.0	1			
	Male	80.0	20.0	245	0.44	1	0.507
	Female	77.3	22.7	181			
	Serengeti	92.7	7.3	123	61.36	3	<0.0001
	NCA	56.2	43.8	130			
	Meatu	82.1	17.9	84			
	Bariadi	89.9	10.1	89			

Reasons for HEC

Possible reasons for HEC according to respondents were crop farms being close to PAs (32.6%, n=446), settlement in the wildlife corridor (7.2%), elephants looking for water in the village land (4.0%), types of crops preferred by elephants (14.6%), increased elephant population (1.3%), and do not know (39.9%).

Human attack by elephants in the area

Generally only (7%, n = 446)of the respondents reported incidents of attacks by elephants in their area. These attacks were either minor (1.8%, n = 446), serious (1.6%), fatal (2.7%), no severe injury (0.9%) and did not report attack by elephants (93%). The attack by elephants occurred at the farm (5.4%, n = 446), homestead (1.3%), others (2.2%) or N/A (91%). Respondents were asked at what time of the day did most HEC incidents occur and majority mentioned nighttime (66.0%, n = 446), daytime (22.4%), both night and daytime (4.3%) and the remaining respondents did not know (6.7%)

Mitigation measures taken by local communities for control of HEC

Mitigation measures currently in place for the control of HEC includes:-noise making

(36.8%, n = 446), chasing by dog (2.5%), using torch (5.6%), set up fire (6.1%), chilli fencing (1.6%), hanging clothes (0.2%), normal fencing (1.6%), assistance from wildlife department (2.6%), communal guarding (0.4%), beehives fence (2.1%), no any mitigation (6.1%), do not know (4.0%) and N/A (30.5%).

DISCUSSION

Local communities' participation to support elephant conservation

Our overall results show that most of the respondents agreed that it is important to conserve elephants and other wildlife while nearly half of the respondents participated in supporting and assisting in the conservation of elephants through different ways. Our finding corroborates with findings from other studies done in the same locations (Walpole *et al*., 2004)as well as other scientists from Congo (Nsonsia *et al*., 2017). Also, the present results show that in the Western Serengeti the education level and sex of the respondents were statistically significant factors in explaining the variations observed towards support of elephants' conservation. Similar findings have previously been reported from Rungwa Game Reserve (Hariohay *et. al*., 2018). Conservation education in rural communities might have positive impacts on issues related to wildlife conservation. It is a necessary management tool to inform and impact conservation knowledge, particularly to local communities, and to enrich traditional knowledge that is useful for sustainable conservation of natural resources (Lyamuya *et al.*, 2016). Whereas, sex might have impact on opportunities, men and women have concerning access, use, management and conservation of natural resources which affects their support on the biodiversity conservation including elephants. This may explain why 55.4% of the respondents did not participate in elephant conservation.

Experience of local communities towards human elephant conflicts

Most of the respondents experienced problems with elephants during the past 5 years and crop raiding was reported to be the greatest problem in the area. Other minor problems were injury, loss of human life, grain store demolished and water infrastructures destroyed. This result is similar with the findings of the previous studies (Mwakatobe *et al.*, 2014; Chang'a *et al*., 2016). Crop raiding by elephants can severely impact local livelihoods and additionally, cause increased labour costs, heightened levels of stress and creates fear (Mukeka *et al*., 2019).

Also, our results show that there was significant difference between districts in experiencing problems with elephants as most of those who experienced problems with elephants were from Serengeti. This observation may be attributed by location of the villages in SE being within wildlife corridor or dispersal areas where elephants spend most of the time during the migration or seasonal movements during different seasons to meet their basic requirements such as water, food, space and habitat; and habitant for breeding, feeding etc.

Reasons for HEC

Possible reasons for HEC were reported to be crop farms being close to protected areas, settlement in wildlife corridors, elephants looking for water in the village land, types of crops preferred by elephants and increased elephant population. This observation indicated that distance from protected areas was the main factor on extent of HEC. Reasons for the HEC in the SE are in line with the findings by Mwakatobe *et al.* (2014). Elephants are more destructive in villages close to protected area than in far distance villages (Mwakatobeet al., 2014; Hariohay *et al*., 2018). Water sources and grazing lands also reported to accelerate HEC in the study area (Estes *et al*., 2012; Bukombe *et al.,* 2020). This indicates the status of grazing land and water points to deteriorate inside protected areas due to increased elephant population and pressure from increased human population around PAs. A total of 6,087 elephants were counted in SE in 2014, suggested a tremendous increase of 98.4% (3,019 elephants) compared to 3,068 elephants that were counted in a similar survey carried out in 2009 (TAWIRI, 2014).

Increasing human populations near PAs has led to an extended pressure on the local natural resources (FAO, 2009). Local communities around protected areas clear wildlife habitats for agriculture and settlements (Estes *et al*., 2012; Yilmato & Takele, 2019). Tanzania is reported to be one of the fastest growing human populations in the world, and its population has increased from 9.1 million people in 1961 during Independence (URT, 2006) to 23.1 million in 1988, 34.6 million in 2002 (Packer *et al*., 2005) and 44.9 million in 2012, with an average annual growth rate of 2.7 (URT, 2012).

Attacks on humans by elephants in the area

Our results also suggested that only few of the respondents reported incidents of attack by elephants in their area and these incidents were either minor, serious or fatal and no severe injury was reported. These attacks by elephants were reported to occur at the farm, homestead and other places. Therefore, these results revealed that attacks on humans by elephants around the SE are insignificant but it needs to be controlled. For effective control of attacks on humans by elephant's hotspot areas needs to be identified and mapped. Most of the HEC were reported to occur during mainly night time compared to day time as well as both night and daytime. While few remaining respondents did not know when those attacks on humans by elephants occur. This observation is similar to other previous studies elsewhere (Mwakatobe *et al*., 2014; Synder *et al.*, 2019).

Mitigation measures taken by local communities for control of HEC

In order to control HEC, local communities in SE use different strategies. Mitigation measures currently in place for the control of HEC included noise making, chasing by dogs using torch, set up fire, chilli fencing, hanging clothes, normal fencing, assistance from wildlife department, communal guarding and beehives fence. This observation concur with reports of other authors in the same location (Mwakatobe *et al.*, 2014; Synder *et al*., 2019) and elsewhere in Africa (Yilmato & Takele, 2019). Local communities adopted different strategies to control HEC and combination of more than one strategy might be more effective to control HEC.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that the majority of the local communities around the SE agreed that it is important to conserve elephants and other wildlife due to their importance to nature and their livelihoods. Generally, local communities around the SE expressed more positive perceptions and were willing to participate and contribute towards elephants' conservation, despite losses incurred from elephants. Most of the households have experienced Human-Elephants Conflicts during the past five years. Crop raiding reported to be the greatest problem in SE followed by human injury, human death, and destruction of food storage facilities and damage of other infrastructures. Therefore, this study recommends firstly that the Management Authorities should provide conservation education to local communities around protected areas that can positively influence their perception toward biodiversity conservation. Secondly, in order to strengthening community participation in biodiversity conservation, special efforts should be done to enhance their involvement in conservation planning and share benefits from wildlife conservation. Thirdly, the use of appropriate mitigation measures to minimize HEC is recommended to reduce negative perceptions to local people towards elephant conservation in the area.

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SOCIO-ECONOMIC IMPACTS OF INVASIVE PLANTS SPECIES TO PASTORALISM AROUND NGORONGORO CONSERVATION AREA, TANZANIA

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ABSTRACT

Rangelands around Ngorongoro Conservation Area (NCA) offer several socio-ecological benefits including provision of grazing land for Maasai livestock. However, the ecosystem is threatened by array of factors including rapid spread of invasive plant species (IPS). This dynamics can potentially affect livestock health and pastoralists' livelihood. Nonetheless, no sufficient evidence on claims above has been established in NCA. Therefore, the study was conducted to investigate on socio-economic impacts of increasing spread of invasive plant species to Maasai pastoralists. To meet the above objective, the study asks the following: (i) How pastoralists perceive invasive species within rangelands? (ii) What are the known major causes of increasing IPS in NCA? (iii) What are the known effects of IPS to human and livestock? (iv) What control methods have been used to suppress IPS in NCA? Three villages, namely Olbalbal, Endulen and Kayepus,were selected for this study. Both households (n = 60) and key informants (n = 10) interviews were used to collected information for this study. Pastoralists recognized IPS more than two decades ago and more than 50% perceived IPS being harmful to public and livestock health. Livestock movement was reported as the major causes of spreading IPS followed by changes of weather condition. Pastoralists indicated lack of awareness on how to control IPS. Only few control methods are used to mitigate spread of IPS, uprooting being the main practice followed by burning. Assessing local awareness provide useful input for setting new targets towards sustainable rangeland management.

Keywords: Threat, Maasai, grassland ecosystem, livestock, wildlife

INTRODUCTION

Increasing population of invasive plant species raises concern about sustainability of rangelands in most tropical countries (Obiri, 2011). Invasive plants species (IPS) are very harmful and can reduce biodiversity integrity and cause dramatic detrimental environmental changes beyond restoration (Vavra, Parks, & Wisdom, 2007). Similarly, they affect human and animal health, water resources and local livelihood (Ngondya, Treydte, Ndakidemi, & Munishi, 2017; Shackleton, Witt, Piroris, & van Wilgen, 2017).

Degradation of rangelands has different implication to its productivity. This includes decreased quality of forage, one of key elements that determine sustainability of livestock production such as amount of milk and meat yield (Holloway, Butts Jr, Beaty, Hopper, & Hall, 1979). Any form of disturbance that affects nutrition and feed supply system to livestock is known to affect their metabolic processes, immunity, reproduction and growth (Leng, 1990). Additionally, rangelands provide wildlife land use (Chaminuka, 2013), thus promoting nature based tourist activities. Different species of fauna and flora have been a special attraction to tourists in most open areas in Tanzania. They contribute significant income generation from local to national level, therefore play important role in poverty reduction and national economic development (Luvanga & Shitundu, 2003; Swanson & Barbier, 1992). It is suspected that the threat caused by IPS affect regional efforts to achieve millennium development goals (SDGs), particularly SDG1 (No Poverty); SDG2 (Zero Hunger); SDGs3 (Good Health and Well Being) and SDG13 (Climate action) (Cumming, *et al*., 2017; Rao, Knight, & Samarth, 2010).

The NCA is among biodiversity hotspot area in Tanzania (Homewood & Rodgers, 2004), whose rangelands have been seriously encroached byinvasive plant species (Estes & Small, 1981). Extensive grasslands, inside and outside the crater are potential pasture resource for Maasai pastoralists whose economy is currently depending on livestock only. Nearly 250,000 cows and 600,000 small stock (goats and sheep) are estimated to coexist with wild animals (NCAA, 2019, un-published report).

Recently, the Management of Ngorongoro Conservation Area Authority (NCAA) has reported the rapid spread of invasive plant species both inside and outside the crater ecosystems. These species are considered as one of potential threat to conservation in the ecosystem (Estes & Small, 1981). For example, in the dry season of 2002, three-quarter of the crater area was colonized, mainly by *Bidens schimperi* and *Gutenber giacordifolia* (Estes & Henderson, 2002).

Usually, pastoralists have indigenous knowledge of the environment where they graze. However, the biodiversity status of most rangelands is changing at rapid rate compared to their adaptive capacity. We suspect that, current spread of invasive plant species could have several socio-economic impacts to local pastoralists in NCA. Unfortunately, little or no information is available on how invasive species affect pastoralism in NCA.

Therefore, we conducted a study to evaluate traditional management of invasive plants species by pastoral community in the NCA. Specifically, the study asks the following major questions;

(i) How pastoralists perceive invasive species within rangelands?
(ii) What are the known major causes of increasing invasive plant species in NCA?
(iii) What are the known effects of invasive plants to human and livestock?
(iv) What control methods have been used to suppress invasive plants in NCA?

MATERIAL AND METHODS

Study area

The Ngorongoro Conservation Area (NCA) is a multiple land use area covering 8,292 km$^{2.}$ The area is important for wildlife conservation, livestock keeping and settlement for the Maasai pastoralists (Sinclair & Arcese, 1995). Three major habitats characterize the area, namely; short grass plains, highlands and the crater (Kabigumila, 1993). Given its unique geomorphology and biotic integrity, NCA is recognized as one of UNESCO World Heritage site, Man and Biosphere Reserve and one of seven wonders of Africa (Masao, Makoba, & Sosovele, 2015). The NCA experiences bimodal rainfall patterns whose distribution is highly influenced by topography. The highland Forest Reserve and the crater receive between 800 and 1500 mm of rainfall per year while the foot of NCA and the Gol mountains receive below 500 mm per year. Grassland is the main vegetation type in the NCA. However, the landscape is characterized with patches of swamps and forest (Kabigumila, 1993). This study was conducted in three villages, namely: Olbalbal, Kayepus and Endulen (Fig.1) which are among the most

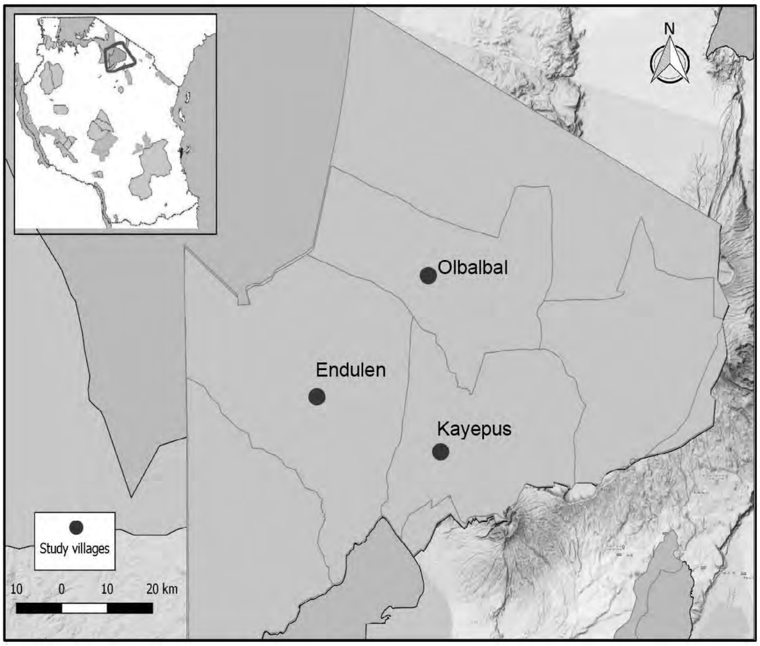

Fig. 1. Map of NCA showing location of study villages

Collecting socio-economic data through interviews

Socio-economic information was collected through households and key informants' interviews (KIs). The former involved in depth interview with head of the household guided by questions in structured questionnaire. Total of 20 households were interviewed in each village, thus making total of 60 households in the entire study area.

On the other hand, KIs (n = 10) involved discussions with staff from NCA, district staff and selected village heads. These meetings aimed to understand involvement of institutions in management of invasive species in NCA.

Before starting each of the meetings above, the informed consent procedure was followed to ensure anonymity of participants regarding their identity and confidentiality. Set of questions were used to guide discussion as shown in attached questionnaires for household interviews and key informants meetings.

Data analysis

To analyze the information provided by respondents from household and key informants' interviews, several participatory approaches were used. Both qualitative and quantitative methods were used to generate data that could be counted, ranked and compared as previously described by (Ager, Stark, Sparling, & Ager, 2011). Qualitative information was analyzed in R (Pinheiro, Bates, DebRoy, & Sarkar, 2018) to generate descriptive statistics like frequency distribution (in percentage). Content analysis was used to analyze qualitative information, like verbal discussions (Hennink, 2013).

RESULTS AND DISCUSSION

Community awareness

Respondents had different memories regarding time when invasive plants species became a problem in their villages (Table1). Majority (>50%) mentioned between the last five (5) to (ten) 10 years. Nearly 20% mentioned more than 20 years ago while very few (<5%) reported the recent five (5) years. This implies that rangelands in NCA have been affected by invasive species for more than two decades, but the seriousness of the problem could be more noticed in recent years. Local communities could be a useful source of historical information that could not be easily retrieved from other sources (Finnegan, 1970).

Additionally, pastoralists' perceptions about the importance of invasive plants species in rangelands were different across all three villages (Fig. 2). Not more than 5% of respondents from each study village considered invasive plants species being nutritious feed materials. This could be associated with fodder scarcity during the dry season. More than 50% considered them being very harmful to both livestock and human health. For example, milk yield, weight loss and diarrhea were reported by more than 50% of respondents while dizziness was the least reported (<10%). This observation suggests that villagers from NCA could have low awareness about socio-ecological challenges of invasive plants species.

Furthermore, only few villagers realized that invasive plants have some effect to human health. For example, nearly 15% of respondents agreed that invasive plants species could cause skin itching while 25% mentioned physical injuries. Concurrently, only few villagers (<5%) realized that invasive plant species have medicinal value. Increasing access to hospitals due to support from NCAA could have reduced community dependency on medicinal plants. The same applies to increased youth enrolment in formal education.

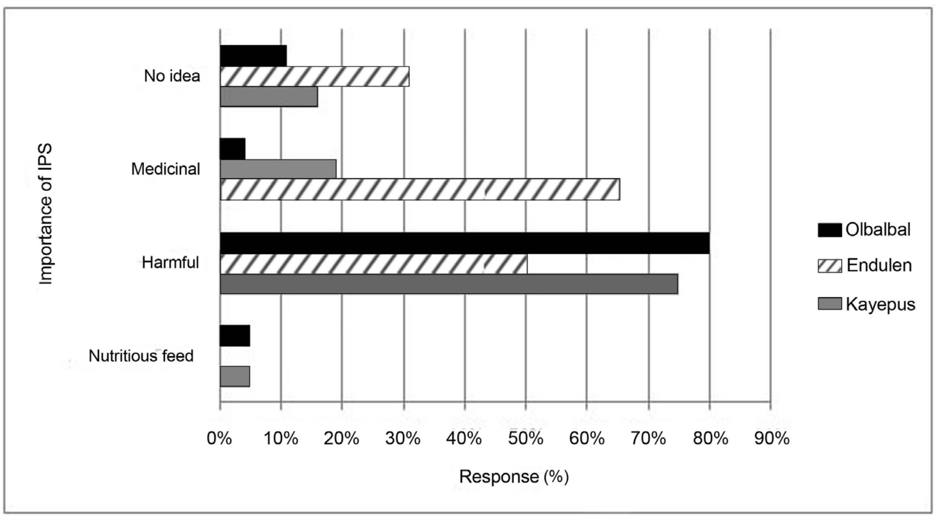

Fig. 2. Importance of invasive species across different villages

Fig. 3. Nightshade plant (*Solanum spp*.)

Spreading of invasive plant species in the NCA

Causes of spread of invasive species in NCA were highly diverse and differed from one village to another (Fig.4). Change of weather condition was most important in Kayepus village while long livestock movements were important in Endulen and Olbalbal village. Influence of tourists and surface water flow were reported by very few meeting participants. Pastoralists' perception about climatic factors could be a reasonable guess. Dynamics of weather conditions, like rainfall or drought would favor some species to perform better than others. Prolonged drought might influence decrease of soil microbes and overall nutrient cycle. Generally, invasive species are relatively tolerant, thus could colonize larger part of ecosystem when soil quality deteriorate.

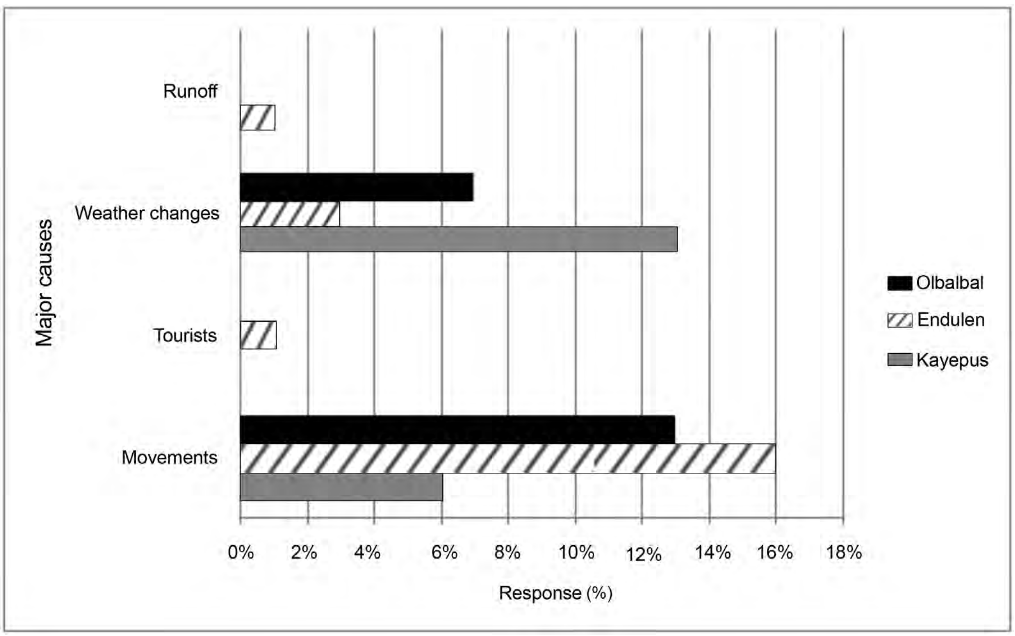

Fig. 4. Spatial variation of factors influencing spread of IPS in study villages.

Control of invasive plants

Only few attempts have been applied to control invasive plant species in the NCA (Fig.5). Probably, most villagers have low awareness about the negative impacts of invasive species to rangelands. About 60% of pastoralists from all surveyed villages have not attempted to mitigate the problem, majority being from Olbalbal (Meshili) village. Uprooting and use of fire were actively applied in Endulen compared to other two villages. Field surveys in Endulen village witnessed more than ten patches of cleared grassland where the Manyata grass (*Eleusinejager*i) dominated. However, slashing has not been attempted in Endulen as it was reported from Olbalbaland Kayepus.

We attribute this difference to limited resources required to control the problem. Being restricted from cultivation practices, Maasai could own very few implements that are commonly used for land management, like hand hoe or rake.

Moreover, use of chemicals to control invasive species was not reported from any of surveyed village. Probably, herbicides are sold expensive compared to actual economic capacity of many villagers. Moreover, the use of herbicides could be prohibited in the NCA because of its ecological significance. Furthers studies are need to determine other non-lethal methods that could be applied to control IPS in NCA.

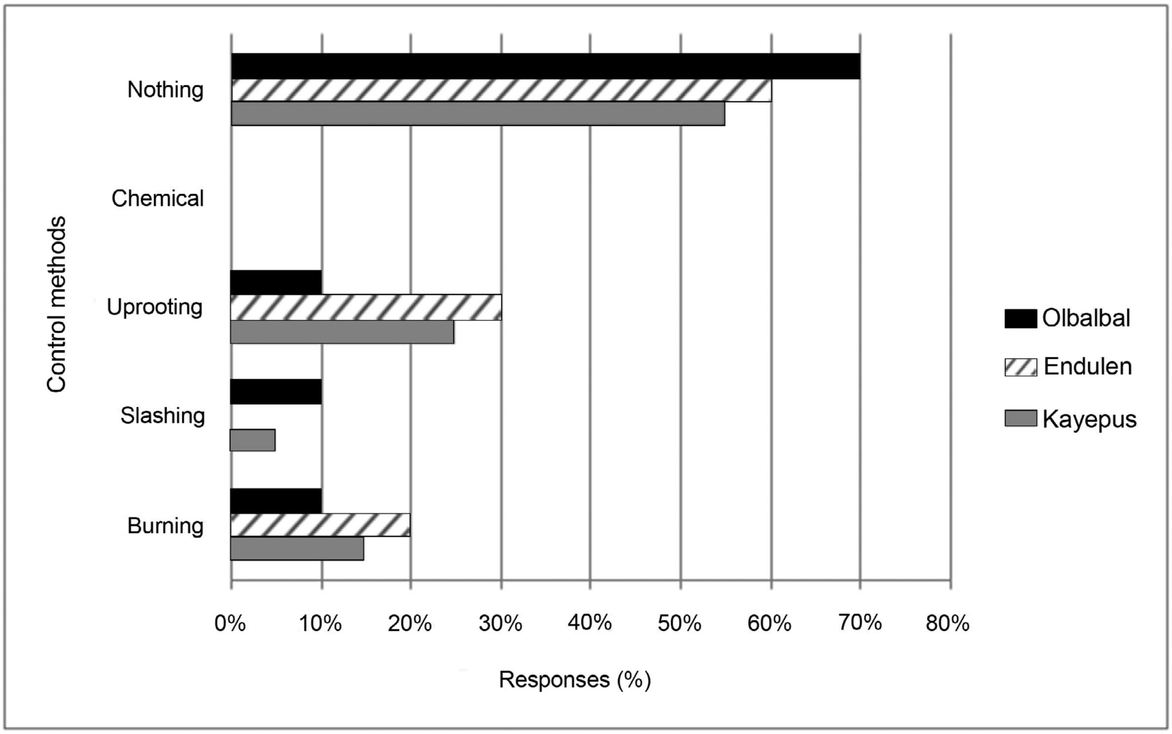

Fig. 5. Spatial variation of methods used to control invasive plants species in study villages.

Fig. 6. Uprooting and burning of Makutian grass(*Eleusinejageri*) in Kayepus village

Conclusions

Pastoralists around NCA already experience number of social-ecological impacts caused by invasive plants species. Although no estimate can be established, we suspect that significant proportion of rangelands is currently less productive for livestock production as before. Since crop cultivation is prohibited in NCA, degradation of rangelands could have serious implication to pastoral economy and food security. To overcome further spread of invasive species, both Management Authorities and pastoral communities need to be sensitized on how to implement best practices for sustainable rangeland management.

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EFFECTS OF THE ABUNDANCE OF PARTHENIUM WEED ON THE COMPOSITION AND DIVERSITY OF OTHER HERBACEOUS PLANT SPECIES IN SIMANJIRO RANGELAND, TANZANIA

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ABSTRACT

Parthenium hysterophorus L. (*Asteracea*e) is an aggressive annual herbaceous plant native to tropical America. It is known to cause distressing effects on natural ecosystems including rangelands in many parts of the world. It has been recently introduced in Tanzania but its effects are not yet quantified, a situation impeding development of mitigation strategies against its spread and effects. Therefore, a study was developed to investigate the effects of *P. hysterophorus* abundance on the composition and diversity of other herbaceous plant species in Simanjiro rangeland, Tanzania. Vegetation data were collected from 60 quadrants of 1m2 each. A total of 14 herbaceous plant species belonging to 13 genera and 10 families were recorded in the study area. *P. hysterophorus* was the most dominant species recorded with greater Importance Value Index (IVI). Generalized linear models (GLMs) showed that the abundance of *P. hysterophoru*s was related negatively to the abundance and diversity of other herbaceous plant species. Moreover, Jaccard's similarity index (0.6) showed a slightly significance difference between the infested and non-infested areas. These findings suggest that *P. hysterophorus* has a potential threat to other herbaceous plant species which are sources of food and nutrients to livestock and wild animals in the area. Thus, integrated management strategies are required sooner than later to control the weed from spreading to other nearby rangelands.

Keywords: dominant species, evenness, invasive weed, parthenium, hysterophorus, richness, Simanjiro.

INTRODUCTION

There is a significant increase in invasive alien species around the world due to an increase in global trade, travel and tourism (Etana *et al*., 2011). These introduced species pose a major threat to biodiversity worldwide (Preisser et al., 2008). According to Dogra *et al*. (2009) invasive species change community composition, deplete species diversity and affect ecosystem processes. It is therefore important to monitor their ecological effects and control their spread in order to reverse biodiversity loss (Andrew *et al*., 2014). However, this requires understanding of the effect of biological invasions on resident plant species in ecosystems (Ehrenfeld, 2008).

An invasive species is one that arrives in a habitat it had not previously occupied, then establishes a population and spreads autonomously (Simberloff, 2010). Species invasions are one of the main conservation threats today and have caused many species extinction (Simberloff, 2003). Once established, invasive species compete with resident species for resources such as light, moisture, nutrient (Vila &Weiner, 2004) and may dominate infested landscapes resulting to the displacement of native plant species as well as decreasing another species diversity (Hejda *et al*., 2009). Majority of invasive species are introduced from elsewhere, although some native species have become invasive in newly occupied habitats (Simberloff, 2010). Invasion by native species in newly occupied habitats falls into two categories, both involving human activities. In the first, a native species that is rather restricted in range and habitat is supplemented with introductions from afar that have new genotypes and the new genotypes, or recombinants involving the new genotypes, become invasive. The second category of native invasive arises from human modification of the environment. For instance, in western Europe, the grass *Elymus athericus*, previously a minor component of high intertidal vegetation, began spreading seaward because of increased nitrogen in both aerial deposition and runoff, and it now occupies most of the intertidal in many areas (Valéry *et al*., 2004).The greatest effects of invasive species entail modifying entire ecosystems, because such modification are likely to affect most of the originally resident species with major negative consequences on ecosystems goods and services delivered by plant communities (Yurkonis *et al*., 2005). However, effects of invasive species on other plant communities should not be generalized since the effects depend on the biological traits of the infesting species and characteristics of infested communities (Andrew *et al*., 2014).

Parthenium hysterophorus L.is an aromatic annual and noxious herb native to tropical America (Veena & Shivani, 2012) and one of the most damaging invasive alien plant species. It quickly dominates native species (Ayele *et al.*, 2014) and therefore threatens biodiversity (Anil, 2014). *P hysterophorus* was most probably accidentally introduced to most tropical and subtropical parts of Africa, Asia and Oceania with cereal and grass seed shipments from America during the 1950s (Bhowmik & Sarkar, 2005).

Studies on the effects of *P. hysterophorus* has been done in different parts of Australia, Asia and Africa but we cannot generalize the effects as the effects depends on the biological traits of the invader and characteristics of the invaded plant communities. Therefore, for finest restoration strategies, it is important to conduct studies focusing on the effects of invasive species on composition and diversity of other plant communities in areas where the invader has established itself (Andrew *et al*.,2014).

This study aimed at assessing the effect of *P. hysterophorus* on other herbaceous plant species within a rangeland in Simanjiro District in Tanzania. Specifically, this study addresses the question that: Does *P. hysterophorus* abundance affects the composition and diversity of other herbaceous plants?

MATERIALS AND METHODS

Study area

The study was conducted in Terrat rangeland in Simanjiro District, northern Tanzania located at 36.6^0 28’42’’S; $3.9^0$43’09’’E and $36.6^0$08 ‘ 83’’S; $3.8^0$85’94’’E and $36.6^0$17’65’’S;$3.9^0$12’4’’E (Fig. 1). The District lies within the Maasai Steppe covering and area of 20,591 km^2 of which 600 km^2 is fertile land, 12,682 km^2 comprised of hunting blocks and the rest is hilly area (Nyaruhucha *et al.*, 2006). The rangeland is adjacent to the Tarangire National Park in northern Tanzania within the semi-arid of the Tarangire-Manyara ecosystems. The ecosystem is one of the most diverse and complex grasslands savanna ecosystems (Msoffe *et al.*, 2010). The soil of the area is also characterized by high levels of phosphorus. The area is characterized by high variability of bimodal rainfall with long rain between January - March and short rains between September-December and frequent droughts (Nyaruhucha *et al.*, 2006). The rangeland supports large groups of Bovidae family, blue wildebeest (*Connochaete staurinus*), family Elephantidae, elephants (*Loxodanta africana*), family *Felidae,* lions (*Panthera leo*), leopards (*Panthera pardus*), family *Hyaenidae*, spotted hyena (*Crocuta crocuta*) and family Canidae, wild dogs (*Lycaonpictus*) (Msoffe *et al.*,2010).The area comprises predominantly Maasai communities where pastroralisim is their major activity to support their livelihood with a human population of 178,693 according to the National Census of 2012.

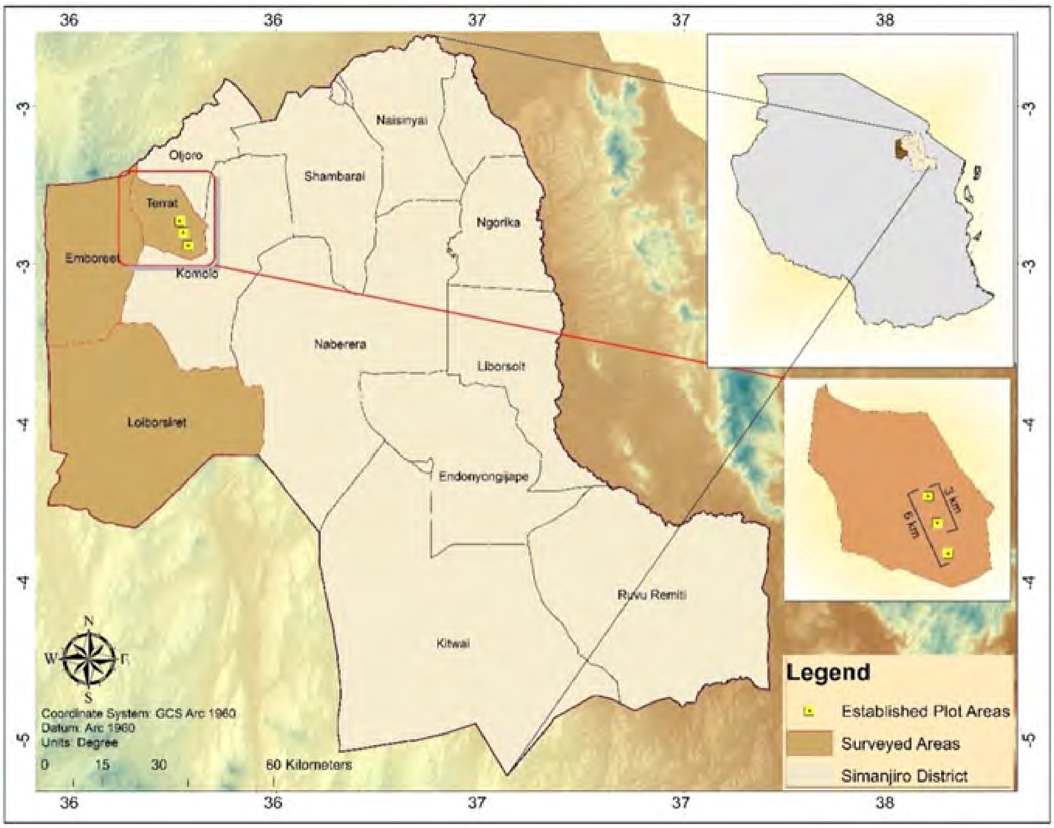

Fig. 1.1. Three clusters in Terat rangeland within Simanjiro District, Tanzania

Study species (*Partheniumhysterophorus*)

Parthenium hysterophorus commonly known as 'altamisa', and famously in Tanzania as carrot weed, while other have named it as bitter weed, star weed, white top, wild fever few, the ''Scourge of India'' and congress grass is an erect, ephemeral herb with a vigorous growth and high fecundity especially in warmer climates, native to north-east Mexico (Patel, 2011). It has now become one of the world's seven most devastating and hazardous weeds (Patel, 2011). It is thought to be introduced in Asia, Africa and Oceania with cereal and grass seed shipment from America during the 1950s (Bhowmik & Sarkar, 2005). Major ecological and morphological characteristics that contribute to its severe invasiveness are its adaptability to wide climatic and soil conditions, its production of allelopathic chemicals and its ability to produce large numbers of seeds 10,000 - 25,000 per plant (Bekeko, 2013). Currently, it is found in some parts of Tanzania and therefore its management is of high concern. Thus, this study focuses on its effects as a weed on range lands specifically in Simanjiro District.

Sampling design and data collection

After reconnaissance survey, the focused to *P. hysterophorus* infested areas as the study interest was to look on the effects of it on other herbaceous species within the rangeland. Since *P. hysterophorus* had only infested a small portion of the rangeland, the area was categorized into three clusters with a distance of 3km apart from each (Fig. 1), clusters were: i) *P. hysterophorus* high infested cluster (HIC) ii) P. hysterophorus low infested cluster (LIC) and iii) P. hysterophorus non-infested cluster (NIC). The distance of 3 km apart between clusters has also been successfully used by Kumari et al. (2014), when studying the effect of *P. hysterophorus* on species diversity in India. Quadrant method and line transect methods were applied in each cluster, whereby a line transect of 100m long was laid out in *P. hysterophorus* high infested cluster, low infested cluster and non-infested cluster. Along each line transect in every cluster, 20 quadrants measuring 1m x 1m (1m2) were demarcated systematically at 5m interval along one side of the line transect, the method has been used successfully by Gebrehiwot & Berhanu (2015) when assessing the effects of *P. hysterophorus* on species diversity in Gamo Gofa, Ethiopia. Within each quadrant, individuals of different plant species were identified, counted and recorded. Most of the plant species collected were identified in the field while those that could not be identified were collected, pressed and transported to Arusha National Herbarium for subsequent identification.

Data analysis

Species richness (S), Shannon-Wiener diversity index (H'), evenness (E) and abundance were computed for each quadrant. Species richness (S) was estimated as total number of species in a quadrant. Species abundance for *P. hysterophorus* and other species were estimated as the relative presence of a species. Species diversity was computed using Shannon Diversity Index. This index accounts for both the abundance and the evenness of the species in natural environment as shown by the equation below (Shannon, 1948). The Shannon index is explained as $H' = -\Sigma p_i \ln p_i$ where H'= Shannon diversity index, pi= the importance value of the ith species in quadrant. Species evenness was calculated as suggested by (Hill, 1973) as $E = H`/\ln S$ where S is the number of species in a quadrant. Species evenness index explains how equally abundant each species would be in the plant community. And when there is no single species dominating the ecosystem the evenness is always high evenness and it is a sign of ecosystem health. Also, species importance value index (IVI %) for each species was estimated as the sum of relative frequency (%) and relative density (%) (Curtis and McIntosh, 1950). Importance Value Index for all species was estimated in order to comprehend the dominance species. IVI %=Relative Density (%) + Relative Frequency (%). Additionally, a similarity index was developed to compare infested and non-infested areas according to Jaccard's formula. This coefficient has been recognized to be robust and unbiased even with small sample size as compared with other similarity indices (Ludwing&Reyonlds, 1988). The similarity index of Jaccard between infested and non-infested area, i and j is given by the following formula: Sij= a/ (a + b + c) where: (a) represents the number of species present in both i and j, (b) represents the number of species in i but not in j and (c) represents the number of species present in j but not in i. The coefficient has a value from 0 to 1, where 1 reveals complete similarity and 0 complete dissimilarity.

Generalized linear models were then used to examine the relationship between community species abundance, diversity, evenness and richness and *P. hysterophorus* abundance. Given that those test with no significance difference were automatically be removed from the model.

RESULTS

Species composition and dominance

The most dominant species within the study area was *P. hysterophorus* followed by *Eleusine indica* (Table 1). A total of 14 species belonging to 13 genera and 10 families were recorded in the study area (Table 2). In *P. hysterophorus* infested cluster we recorded ten different species belonging to nine families with two species of high value in grazing, *Eleusineindica* and *Cynodon dactylon.*

Table 1: Importance Value Index (IVI) for recorded species in areas with high, low and non-infestation of *Parthenium hysterophorus*

Species name	IV (%)	Species name	IV (%)	Species name	IVI (%)
Parthenium hysterophorus	43	*Parthenium hysterophorus*	36.2	*Eleusine indica*	35.4
Eleusine indica	25	*Eleusineindica*	7.9	*Tribulus terrestris*	8.1
Amaranthusspinosus	10	*Tribulus terrestris*	2.8	*Cynodon dactylon*	7.4
Tribulusterrestris	7.9	*Tephrosia purpurea*	1.9	*Cyperus rotundus*	6.7
Portulaca oleracea	6.21	*Cynodon dactylon*	1.2	*Portulaca oleracea*	6.5
Calotropis gigantean	5.7	*Portulaca oleracea*	0.2	*Calotropis procera*	6.5
Cynodon dactylon	4.4	*Calotropis gigantea*	0.2	*Echinocloacolona*	6.4
Solanum campylacanthum	3.2	*Cyperus rotundus*	0.06	*Solanum campylacanthum*	6.1
Cyperus rotundus	2.3	*campylacanthum*	0.03	*Eragrostis aspera*	5.9
		Amaranthus spinosus	0.02	*Ipomoea hildebrandtii*	3.7
				Amaranthus spinosus	0.3

Table2: Name and families of species recorded in all three clusters studied

Species name	Genus	Family
Parthenium hysterophorus	Parthenium	Asteraceae
Eleusine indica	Eleusine	Poaceae
Amaranthus spinosus	Amaranthus	Amaranthaceae
Tribulus terrestris	Tribulus	Zygophyllaceae
Portulaca oleracea	Portulaca	Portulaceae
Calotropis gigantean	Calotropis	Apocynaceae
Cynodon dactylon	Cynodon	Poaceae
Solanum campylacanthum	Solanum	Solanaceae
Cyperus rotundus	Cyperus	Cyperaceae
Tephrosia purpurea	Tephrosia	Fabaceae
Ipomoea hildebrandtii	Ipomoea	Convolvulaceae
Echinoclea colona	Echinoclea	Poaceae
Eragrostis aspera	Eragrostis	Poaceae
Calotropis procera	Calotropis	Apocynaceae

Comparison between infested and non- infested areas

The results from Jaccard's similarity coefficient showed a value of 0.6 in a comparison between *P. hysterophorus* high infested cluster and non-infested cluster. Similarly, a coefficient showed a value of 0.6 when *P. hysterophorus* low infested cluster was compared with and non-infested.

Effect of *P. hysterophorus* on other herbaceous plant species

There was a significant negative relationship between the abundance of *P. hysterophorus* and the abundance and diversity of other herbaceous species (Table 3). Furthermore, the abundance of *P. hysterophorus* showed no significance difference with the evenness and richness of other herbaceous plants and hence removed from the Generalized linear Model.

Table 3: Effect of the abundance of *P. hysterophorus* **on diversity and abundance of other herbaceous plants**

	Estimate	Standard Error	*p*-value
(Intercept)	6.093	0.034	0.001
Diversity	-0.9423	0.033	0.001
Abundance	-0.0023	0.0002	0.001

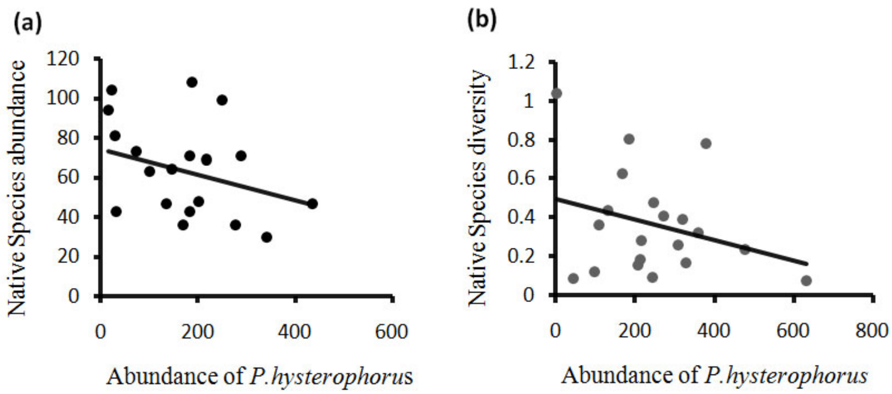

Fig. 2. The relationships between *P. hysterophorus* abundance and native herbaceous species (a) native species abundance, (b) native species diversity in Simanjiro rangeland, Tanzania.

DISCUSSION

Species composition and dominance

The number of 14 species recorded is relatively low this might be due to the fact that the area is semi-arid in nature. Among all the species recorded *P. hysterophorus* was the most dominant species (Table 1) with greater Importance Value Index (IVI) as compared to all other plant species. Similar results were found by Huy & Seghal (2004) who found greater IVI on *P. hysterophorus* an indication of the domination character of the weed. Also, Khan *et al.* (2014) confirmed that importance value index (IVI) showed the superiority of *P. hysterophorus* in Peshawar valley, Pakistan. The domination of *P. hysterophorus* could be due to its high invasive capacity, allelopathic properties, short life cycle and prolific character (Dalip *et al*., 2013). This might be due to its high growth rate and ability to exclude the growth of other species. Similarly, Belachew & Tessema (2015) showed that *P. hysterophorus* as the most competitive species in Ethiopia.

Comparison between infested and non-infested *P. hysterophorus a*reas

Results showed high similarity between the infested and non-infested area, this indicate that there is no fundamental change in species composition within the area. Similarly, Kumari *et al*. (2014) observed no major difference in species composition between Parthenium weed infested and non-infested area in cultivated fields of Bilaspur, India. The similarity between infested and non-infested area might be due to a short time since the introduction of the weed in the area as *P. hysterophorus* achieved a major weed status in India and Australia after decades (Bhowmik *et al*. 2007). Therefore, with time if *P. hysterophorus* remains uncontrolled fundamental changes in species composition within the area are expected to occur.

Effects of the abundance of *P. hysterophorus* on community structures of other herbaceous plants

There was a negative significance relationship between the abundance of *P. hysterophorus* and the abundance and diversity of other herbaceous species (Table 3). This suggests that P. hysterophorus significantly decreased the abundance and diversity of other species (Fig. 2(a)-(b). Similarly, Mekonnen (2017) reported the reduction in species diversity as the result of the high abundance of P. hysterophorus in Ethiopia. Studies in Australia (Grice, 2006) and India (Kohli *et al*.,2004) have also found a decrease in plant diversity as the result of *P. hysterophorus* invasions.

There was no significance difference between the abundance of *P. hysterophorus* and species richness. This finding is contrary to that of Kohli *et al.* (2004) who reported a significant decrease in species richness from 68 to 32% in invaded areas in the lower Himalayas, India. Lower than expected effect of the abundance of *P. hysterophorus* on species richness in our study may be due to the semi–arid nature of the study area which makes the area poor in species richness. Furthermore, *P. hysterophorus* is also a recent introduction to Tanzania (Clark &Lotter 2011), so the effects on species richness will only become evident after many years.

This study has also revealed that there was no significance difference between species evenness and the abundance of *P. hysterophorus.* This could elucidate that *P. hysterophorus* has not established itself in the manner that has affected the ecosystem health, which is also an evident that the weed is still in the initiation stage of infesting the area. As Belachew & Tessema (2015) supported that the evenness of species declined with increasing spread of *P. hysterophorus* suggests negative influence that *P. hysterophoru*s had on the status of species evenness. Seta *et al.* (2013) and Dalip *et al*. (2013) reported that *P. hysterophorus* had negative significance difference on species evenness in Mehari Sub-Watershed of Rajouri Forest Range, India and in Gedeo Zone, Southern Ethiopia respectively.

CONCLUSION AND RECOMMENDATION

The study has revealed that *Parthenium hysterophorus* is dominant weed and has negative effect on the diversity and composition of native herbaceous plant species. Therefore, monitoring of the species' spread rate and its impact on native flora is important in order to develop management control strategy. Is also further recommended that, there should be deliberate efforts on the ground to contain the spread of *P. hysterophorus* into protected areas in Northern Tanzania.

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USE OF REMOTE SENSING TECHNOLOGYFOR BIODIVERSITY MONITORING AND CONSERVATION OF MOUNT KILIMANJARO NATIONAL PARK ECOSYSTEMS

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ABSTRACT

Climate and land use change have become serious challenges facing protected areas globally, more so those in the tropical mountainous forest ecosystems. Kilimanjaro Mountain National Park was specifically designated to protect and safeguard the highest free-standing mountain in the tropics, with its snow-capped summit throughout the year. The park attracts thousands of national and international tourists annually because of its snow capped-summit, as well as its altitudinal gradient representing the different eco-climatic zones of the world. In turn, earnings from tourism boost the country's economy while ensuring the sustainability of this unique glacial-tropical mountainous forest ecosystem park. While repeated measures of biodiversity and environmental parameters are the norms in ensuring ecological monitoring of the park and its surrounding ecosystems are kept in check, efficient implementation of the same are hardly feasible due to labor intensive in-situ observations. This research explored the use of Remote Sensing (RS) data from the European Satellite Agency (ESA) – Sentinel- 2 Satellite Mission-Multi-Spectral Instrument (MSI), in developing a state-of-the-art monitoring protocol. Data were downloaded from Sentinel 2 A & B, and pre-processed via its Sentinel Application Platform (SNAP) software. Further Image processing, functions development for the model automation were performed in the R software-using the R-Studio environment. The automated models developed in R were used in generating the vegetation and Bio-physical Indices parameters from the RS data. These Indices were further exported as image files (GeoTIFF) into GIS software for the results visualizations, overlays with vector data and sharing outputs as image web services applications. The developed methodology ensures that essential environmental parameters indices, required in monitoring the vast areas of the park and its surroundings in the short-term (including current) and long-term scenarios using up to date, high resolutions and frequently available RS data from the Sentinel-2 Sensors are captured.

Keywords: Climate- Land-Use Change, Kilimanjaro-Mountain NP, Remote Sensing, Sentinel-2, Vegetation-Biophysical Indices.

INTRODUCTION

It is well known that protected areas particularly those in the tropics faces key challenges linked to loss of wildlife habitats, mainly due to land use changes in their surrounding ecosystems whilst exacerbated by the increasing impacts of global climate change (Peterset al., 2016; Burgess *et al.*, 2017; Tabor *et al.*, 2018). Kilimanjaro Mountain National Park (KINAPA) and its associated ecosystem represents such a world-wide unique and diverse habitat, with an attitudinal range of over 5,000m above sea level, with climate and vegetation zones changing from the tropical savannas at the lowlands to the afro-alpine grasslands at the top (Hemp, 2009). Apart from the natural ecosystems within the national park, several land uses occur in the vicinity, including intensive annual monocultures (maize and other cereals), perennial coffee-plantations to diverse traditional agro-forestry systems of Chagga-Home-gardens which to some extent retains a semi-natural forestry structure (Hemp *et al.*,2018).

This highest free-standing mountain in Africa acts as a water tower, feeding major river systems, and plays a major role in the regional climate regulation, while providing many other important ecosystem services to the locals and beyond (Hemp &Hemp, 2018). Its melting "ice cap", which is an important tourism attraction by mountaineering and tourists visiting the park every year, though caused by decreasing precipitation (Hemp 2005; Thompson *et al.*, 2002) rather by increasing temperature, has become a global symbol for the accelerating trend of global warming. The KiLi-Project, funded by the German Science Foundation (DFG) studied the influence of Climate and Land-Use change on biodiversity and multiple ecosystems processes on Mount Kilimanjaro from Sixty Five established plots, across Twelve different land covers and land uses along the elevation gradient (vertically from the lowlands of Colline savannas to the highest peak of vegetation layer dominated by the Hellichrysum) and across the land use gradient from the protected tropical montane forest of Kilimanjaro National Park to the disturbed lowlands of the savannas currently converted to intensive monoculture crops cultivation (Applehaus *et al*., 2016).

This study, capitalizes on the recently concluded KiLil-Project (2010-2018), with the main objective of a follow-up monitoring strategy for the park (KINAPA), being the custodian for ensuring the continuity of the ecosystem services provided by the park to the local and the international community at large. Apart from the direct ecosystem services provided by the park in its natural settings, it is particularly key tourist destination in the country, contributing to the local and national economy from the foreign currency accrued through the tourism business at KINAPA and its tripling effects to the local communities surrounding the park. In doing so, KINAPA is vested with the responsibility of protecting this uniquely massif standing tropical montane cloud forest in the long run,at the face of its increasingly isolation from its surroundings, mainly through habitat conversions from the natural forest vegetation to croplands because of the adjacent intensifying land uses spearheaded by the increasing human population pressure (Hemp & Hemp, 2018).

The study explored the use of remote sensing by deploying the current state of the art from the Sentinel-2 Multi-Spectral Instrument (MSI) satellite of the European Satellite Agency (ESA), in designing an ecosystem, biodiversity and conservation remote sensing monitoring tool. The deployment of this monitoring tool will enable "in-situ repeated observations up-scale", which are hardly feasible in such a large protected area's challenging ecosystems by park staff. The currently available data from the Sentinel-2 MSI provides multi-spectral bands with high spatial resolutions and quick revisit time often days before sentinel 2 B and five days for both sentinel 2 A & B (ESA, 2017). The Sentinel- 2 MSI is comprised of 13 multi-spectral bands ranging in resolutions from 10 m, (four bands) inclusive of the visible wavelengths; 20 m (six bands) inclusive of the new "Red-Edge", near-infra red (NIR) and short-wave infra-red wavelengths; important for vegetation monitoring and with high capabilities for use in ecosystem, biodiversity and conservation monitoring (Drusch *et al*., 2012). The other three bands are of 60 m resolution including the Aerosol, Water Vapor and Cirrus band. Spectral signatures and derived indices like the Normalized Difference Vegetation Index (NDVI) are used as a standardized way to measure the health of vegetation by quantifying the ratio of the difference between the NIR (strongly reflected by vegetation) and Red (absorbed by vegetation).

NDVI values ranges from -1 to + 1, with a distinct boundary for each type of land cover. Negatives likely represent water, while positives close to one indicate dense green leaves. However, values close to zeros represents no leaves (green vegetation) or degraded forest. In this research project, Sentinel – 2 MSI spectral bands and derived products,including the Vegetation and Biophysical Indices such as NDVI and their derivatives were explored and analyzed with the following objectives;

- Explore current RS Data and Methods in developing a biodiversity and conservation monitoring tool in the Kilimanjaro National Park and its surrounding ecosystems
- Link remote sensing derived information with in-situ data and predict/retrieve spatially explicit biodiversity measures
- Explore the power of RS Data in biodiversity analysis and its contribution to a deeper understanding of the biodiversity and potential linkages to ecosystem functions along climatic and anthropogenic disturbance gradients at Mt. Kilimanjaro

MATERIALS AND METHODS

Study Area

The Kilimanjaro Mountain National Park and its ecosystems, is located in the north-east of Tanzania and spans an elevation gradient from the colline savanna plains (~ 700 m a.s.l.) to the glaciated areas encircling Kibo summit (5895 m a.s.l.). Its equatorial daytime climate is shaped by the passing of the intertropical convergence zone, with more than half of the annual rainfall occurring during the so called long-rainy season (March-May), Applehans, *et al.*, (2016). While annual precipitation amounts to more than 2500 mm in the southern montane forest belt, the northern mountain side (lee ward) receives hardly more than 1000 mm (Hemp, 2005; Detsch *et al*., 2017).

The mountain's belt-like vegetation zonation (Fig 1) is characterized by major land-cover transitions at short horizontal distances resulting from changing climatic conditions and anthropogenic interferences (Hemp 2009). This study covered the land-cover distributional zones which were marked by the 65 Kili-Research Project Plots (Hemp *et al*., 2018), which were distributed along the mountain elevation gradient; from the lowlands of Savanna vegetation to the top elevation zone covered by the *Hellichrysum Spp*. Plots were also selected to cover twelve land-cover uses, from the total protected forests in the park, dominated by Ocotea, Podocarpus and Helichrysum vegetation to the intensive monoculture crop cultivation dominated by Maize and theCoffee plantations (Applehans *et al*., 2016).

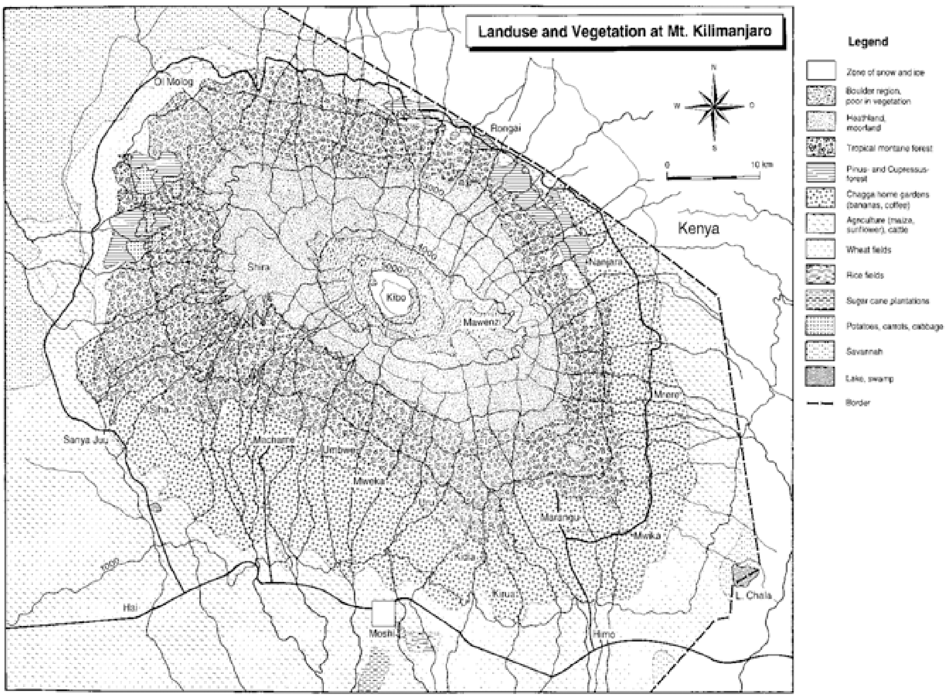

Fig. 1. Map of Kilimanjaro Mountain showing elevation land-cover use gradients (Hemp 2009)

Sentinel 2 MSI Data Sets

Sentinel 2 datasets used in this study were downloaded from the ESA-Corpenicus Website, https://sentinels.copernicus.eu/web/sentinel/sentinel-data-access/registration last accessed February, 2019. The Kilimanjaro is covered with two-sentinel 2 tiles area wide; the T37MBS on the western side and the T37MCS on the eastern part according to the date of acquisition, in this case scenes taken between 2016 and 2019 Sentinel 2 A and B were searched and downloaded for the study area. The selected scenes were chosen basing on the level of cloud cover percentages in order to obtain good quality images. However, given the nature of the Kilimanjaro, being a tropical cloud montane forest, it is almost impossible to acquire cloud-free scenes at any time of the year. Images were downloaded from both sentinel 2 A and 2B, as Level 1 C Top of Atmosphere corrected products, through the Sentinel Application Platform (SNAP) Software which is also available for free through downloading at the ESA-Copernicus website, with its associated Plug-ins, for the pre- and processing of the Sentinel data.

The downloaded images were further processed for atmospheric effects from the top of atmosphere Level 1C to bottom of atmosphere Level 2A products, using the Sen2CorPlugin from SNAP (Wilm, 2018). In order to automate the process, the image products (L1C) were exported from the SNAP-graphical processing tool (.gpt) into the R software, as .xml files for commands and functions creation using the R Studio processing environment. In R, image files were further corrected for atmospheric effects, to Level 2A products using the Sen2Cor operator. Image outputs were then used for the follow-up stages of extracting the various vegetation and biophysical indices from the sentinel-2 imagery data. In order to create a cloudless image, the T37-MBS and T37-MCS tiles had to be processed separately before mosaicking of the tiles using the Cloud-Mask layer, also produced as part of the level 2A processing output, also performed in R as shown in Figure 2.

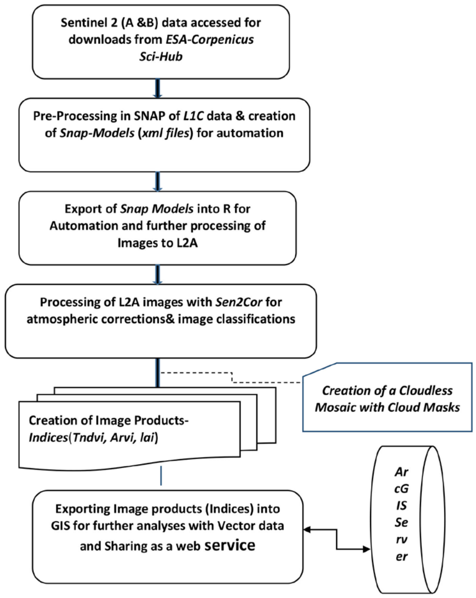

Fig. 2. Workflows for access, processing and sharing Outputs of Image Data from Sentinel-2 through the Tanzania National Parks (TANAPA) GIS Server

Vegetation and Biophysical Indices Derived from Sentinel 2 Data

Creation of commands-data models for indices extraction automation was also performed after the atmospheric corrections for each of the scenes, according to the date of acquisition, as year, month and day for the matching tiles. In order to ensure that the sampled indices from the Level 2A image products were not affected by clouds, further processing of the Level 2A image scenes using cloud masks application, as a by product of sentinel-2 data from the classification, was performed in R.Several vegetation and biophysical indices were then extracted using the created Snap Models function in R, after which the outputs were exported as image files (Geotiff) into the GIS (Qgis/ArcGIS) for visualizations and further analyses, including overlaying with the plots for final products outputs and sharing with park staff as web-service maps through the Tanzania National Parks (TANAPA) server, located at the headquarters office in Arusha.

RESULTS

Several Vegetation and Biophysical Indices were derived from the final Sentinel- 2 images that were chosen based on the quality of their scenes output from the processes described in 2 above, with their descriptions in Table 1, and a few of the selected indices are presented in Figure 3.

Arvi maps (2019, 2018 and 2017 derived indices)

The Atmospherically Resistant Vegetation Index (Arvi), resistant to the atmospheric effects (in comparison to the NDVI) is accomplished by a self-correction process for the atmospheric effects on the red channel. Arvi takes advantages of the different scattering responses from the blue and red bands to retrieve information regarding the atmospheric opacity (the blue sky). These properties therefore have determined that Arvi, has a similar dynamic range to the NDVI, but is on average four times less sensitive to the atmospheric effects than the NDVI. Areas of dense green vegetation (the montane forest belt) showed clearly high reflectance (more brightness) compared to non-vegetated areas of the Kilimanjaro (Fig 3).

Ireci maps (2019, 2018 and 2017 derived indices)

The Inverted Red Edge Index (Ireci) algorithm incorporates the reflectance in four bands to estimate canopy chlorophyll content. The “red edge” is the name given to the abrupt reflectance change in the 680±740 nm region of vegetation spectra that is caused by the combined effects of strong chlorophyll absorption and leaf internal scattering. The position of the red edge has been used as an indication of stress and senescence of vegetation, as depicted from our results, time series shows a darker tone in areas void of vegetation compared with areas of the tropical montane forest belt, with brighter tones, for all the years; 2017 to 2019 (Fig. 3).

Tndvi maps (2019, 2018 and 2017 derived indices)

The transformed Normalized Difference Vegetation Index (Tndvi) algorithm indicates a relation between the amount of green biomass that is found in a pixel and it's the square root of NDVI. It is superior to NDVI in that it has higher coefficient of determination for the same variable and always has positive values and the variances of the ratio are proportional to the mean values. Due to limitations from effects of clouds for obtaining more quality data, Tndvi would be preferred over NDVI in areas of cloud forests like Kilimanjaro, where NDVI becomes sensitive at high values of biomass.

Table1: Vegetation Indices derived from Sentinel 2-MSI Sensor Products used in this study between year 2017-2019; for both tiles T37-MBS and T37-MCS of the Kilimanjaro ecosystems

Index	Index Application	Derived formula from image bands
NDVI	Normalized Difference Vegetation Index (The most commonly used in RS studies) its values range between -1 and +1 (Rouse, et al. 1973)	NIR-RED/ NIR+RED
RVI	Ratio Vegetation Index, also known as Simple Ratio has high reflectance for vegetation than soil, water and snow- preferred for mapping vegetation (Jordan, 1969)	NIR RED
ARVI	Atmospherically Resistant Vegetation Index, accomplishes self-atmospheric corrections in the red channel (Kaufman & Tanre, 1992	NIR-RED-y(RED-BLUE)/ NIR+RED-y(RED-BLUE)
TNDVI	Transformed NDVI- preferred because it's the square root of NDVI and so its values are always positive (can be larger than 1) (Senseman, et al. 1996)	√ (NIR-RED + 0.5)/ NIR+RED
IRECI	Inverted Red Edge Chlorophyll Index utilizes the Red-Edge bands (bands 5, 6 & 7) currently present in sentinel 2 data (Clevers, et al. 2002)	(NIR *NIR-RED1*RED1)/ (RED2*RED2/RED3*RED3)
GNDVI	Green Normalized Difference Vegetation Index is strongly correlated to the leaf area index and hence chlorophyll content (Gitelson, et al. 1996)	NIR- GREEN/ NIR+GREEN
NDI45	Normalized Difference Index is more linearly, less saturated at higher values than NDVI, (Delegido, et al. 2011b)	(NIR*NIR- RED*RED)/ (NIR*NIR+RED*RED)
TSAVI	Transformed Soil Adjusted Vegetation Index is used to correct the effects of soil line arbitrary values due to slope/terrain of the area on vegetation (Baret & Guyot, 1991)	(NIR*NIR-s *RED*RED-a)/ (a*NIR*NIR+RED*RED-a)

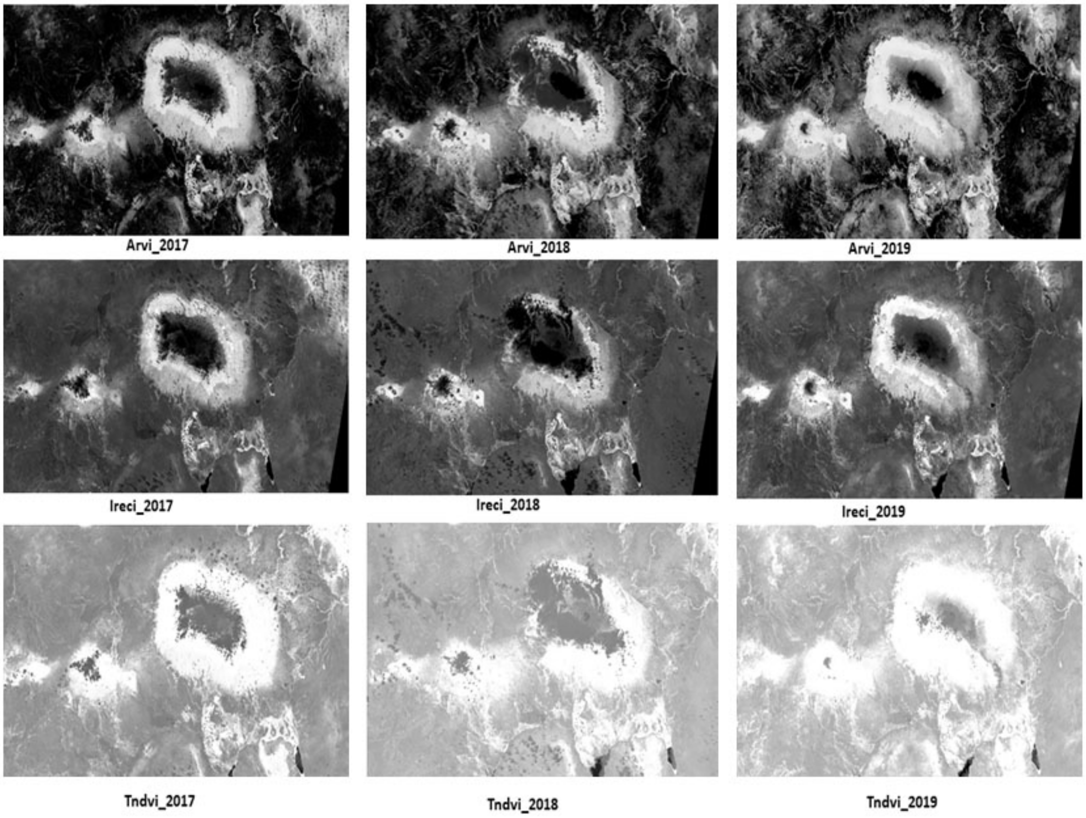

Fig. 3. Derived vegetation indices from the sentinel-2 data for the Kilimanjaro between 2017 and 2019. Bright areas represent high values and dark areas low values of vegetation coverage. (Arvi= atmospherically resistant vegetation index; Ireci=Inverted red-edge chlorophyll index; Tndvi= Transformed normalize difference vegetation index).

DISCUSSION AND CONCLUSIONS

This study introduces the use of current remote sensing sensors capabilities, in particular the Sentinel- 2 MSI sensor of ESA, in the ecological, biodiversity and conservation monitoring, much needed in managing vast protected areas such as KINAPA and its ecosystems. Previous research work indicated that future climatic characteristics of the Kilimanjaro ecosystems are mainly determined by the local land-use and global climate change (Thompson *et al*., 2002; Detsch *et al.,* 2017; Hemp & Hemp, 2018), and therefore it is imperative that KINAPA management is able to consistently carry out a monitoring protocol for the key biodiversity and environmental parameters in the long run. A model which was also automated for use by park staff has been customized in such a way that it can be easily followed through the set-up work flows developed, even with non-RS experts. Just with a minimum of a computer that is connected to the ArcGIS Server atTANAPA headquarters in Arusha through the internal network,the data model output is uploaded and accessed for sharing using the available web-services in the ArcGIS server network.

Preliminary results from the derived indices in this study show that Sentinel-2 data provide the ability to carry out consistent monitoring work at high spatial resolutions ranging from 10m, while providing a wide opportunity for the use of the RED-Edge bands (bands 5, 6, 7) for a vast of biodiversity measurements for ecosystem monitoring (Rocchini *et al*., 2015). This is because RS allows measurements of large regions in a short period of time and provides so continuously information about vegetation distribution (Wang *et al*., 2006). The reflectance and emission of light from the Earth's surface can be directly related to physiological, morphological and structural composition of plants (Jetz *et al*., 2016). Several studies have proven a significant correlation between species richness and spectral indices (Peterset al., 2016; Wang *et al*., 2006). The most common used indices are NDVI, capturing the greenness and chlorophyll content. GNDVI, a modified form of NDVI (Clevers *et al.*, 2002), linearly correlates with LAI. The transformed soil adjusted index (TSAVI), which corrects the variations of soil background (Huete, 1988) and RVI, a simple ratio between Red and NIR have also been used in various studies for assessing and monitoring biodiversity in tropical forest ecosystems (Rocchini *et al*., 2015). All these indices were explored in the study for potential monitoring of key biodiversity parameters at KINAPA and its ecosystems in the short and long term, where frequent in-situ observations by field staff may be difficult given the nature of the terrain of this unique cloud montane forest.

The use of the Sentinel-2 data products studied here will enable an integrated ecosystem measurement and monitoring, through the derived indices of vegetation like the NDVI- and its derivatives including TNDVI, ARVI, IRECI, TSAVI and moreas well as the biophysical indices, such as the leaf area index (LAI) and fraction of vegetation cover (FVC),(Wang *et al.*, 2018),urgently needed to monitor these vast areas, while contributing to the global biodiversity conservation and monitoring agenda, especially needed in achieving the Aichi Conservation Targets (2011-2020), in developing essential biodiversity variables (EBV) from RS data (Alleaume *et al*., 2018; Skidmore *et al*., 2015).

Different spectral bands combination derived from Sentinel-2 sensors, ranging from the visible, red-edge, near and short infra-red spectra,important for biodiversity monitoring have been explored in this study, particularly in the derivation both vegetation and biophysical indices for ecological, biodiversity and conservation monitoring purposes. It was also established that the use of the transformed NDVI, TNDVI, would be preferred for comparisons of time series, where vegetation phenology analyses may present a challenge, due to lack of consistency of image data that are also cloud free, caused by the nature of the cloud forests, like in the Kilimanjaro Mountain ecosystem. Further work in this study would explore the variances in the ratios obtained for the different indices' types derived here in relation to each of the research plots/sampled sites, along the elevation gradient as well as across the different land cover/uses gradients in the study area.

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TESTING LOW COST SOLUTIONS TO MITIGATE HUMAN-WILDLIFE CONFLICT: A SUCCESS STORY FROM WEST KILIMANJARO, TANZANIA.

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ABSTRACT

Human-wildlife conflict (HWC) is an increasing threat to conservation and community development. Communities are recognized as the first line of defense against the illegal wildlife killings and trade (IUCN, 2018), yet, community members suffer the most from the presence of wildlife. In many remote rural settings, living with wildlife is an expensive exercise that, in spite of the efforts to increase financial benefits from wildlife conservation, has so far brought little change to households' income. Human-wildlife conflict drives livelihoods and wildlife destruction, food insecurity, occasional loss of human lives, and it is increasingly used to drive political agendas, yet,human encroachment of wildlife corridors is destroying vital natural connectivity, creating more hotspots of HWC. In this short paper we review a user-friendly Human Wildlife Conflict toolkit tested over 1000 cases of crop raiding events in West Kilimanjaro, Tanzania. The initiative is part of the EU-funded project CONNEKT (Conserving Neighbouring Ecosystems in Kenya and Tanzania – FED/2017/394-715) and paves the road to reduce costs from coexisting with wildlife. The project has trained and equipped farmers from Enduimet Wildlife Management Area with tools to decrease crop losses from wildlife invasions. Following training Village Crop Protection Teams and testing the toolkit for 18 months, we found that two tools in particular were able to resolve more than 80% of the wildlife-conflict events, considerably reducing the impacts from HWC, and the cost of the toolkit.

Keywords: Conflict Mitigation, Human-wildlife Interactions — Rural Communities–Coexistence, toolkit.

INTRODUCTION

Human–wildlife interactions resulting in loss of crops and livestock, property damage, and human injury pose significant challenges to global conservation efforts (IUCN,2003). In East Africa, the increase in human-wildlife conflict is mostly driven by land use changes in areas surrounding Protected Areas (PAs), where dense human populations live in close proximity to nature, and where livestock holdings and crop fields form a significant part of rural livelihood, bringing difficulties for community-based conservation to succeed (Dickman, 2010). PAs are increasingly becoming islands of habitat surrounded by seas of cultivation and development (Madden, 2004). The expansion of small holder cultivation has been reported to reduce connectivity among PAs and decrease wildlife home ranges due to loss of habitats and fragmentation, leading to increased conflict and creating negative impacts to both wildlife and local communities (Distefano, 2005). Although ecosystem-based approaches (including the development of corridors between protected areas) offer improved long-term protection for many species, they also involve regional opportunities for interaction and conflict between local people and wildlife (Madden & McQuinn, 2015). As a result, both people and wildlife suffer tangible consequences, creating the need for management response to conflict incidents, preventive and mitigation strategies to protect biodiversity and support household livelihoods (Lamarque *et al*., 2009).

Global efforts focus on balancing trade-off in local communities near the borders of Protected Areas, establishing good management practices in order to promote the coexistence and minimize the conflict benefits greatly from a behavioural change in both humans and the wildlife species at the source of the conflict (Branco *et al*., 2019).

METHODS

Study area

One of the aims of the European Union-funded CONNEKT project is to decrease the costs of living with wildlife while conserving the critical transboundary area of the Greater Kilimanjaro Ecosystem (Fig.1). This landscape is one of the richest in biodiversity and hosts one of the most important wildlife corridors in Tanzania, the Kitenden corridor, providing connectivity between Mount Kilimanjaro in Tanzania and Amboseli National Park in Kenya (Riggio & Caro, 2017). Enduimet Wildlife Management Area (EWMA)occupies the northern boundary of Longido district (Arusha Region), covers 752 km2 and it is bordered by Kilimanjaro National Park to the southeast, the Tanzania-Kenya border to the north and Ngasurai plains to the west. The Acacia woodland of the EWMA hosts a variety of wildlife, including large carnivores and herbivores. Human Wildlife Conflict in the Greater Kilimanjaro Ecosystem is increasing due to land conversion and expansion of croplands, increased livestock and more sedentary pastoralist communities.

Data collection

In rural settings, living with wildlife is an expensive exercise that, in spite of the efforts to increase financial benefit from wildlife conservation, has so far brought little change to households' income (Gillingham and Lee, 2003, Lamarque *et al.*, 2009). The HWC toolkit presented was originally tested by Honeyguide Foundation andaims to increase the capacity of small-scale farmers to reduce costs of living with wildlife by protecting livestock and crops. A complete HWC toolkit is composed by a strong LED flashlight (2000 Lumens), air horn, chili bombs and roman candles. The four tools can be used sequentially (torch-airhorn-chili bomb-roman candle), with the use of explosives as a very last choice against very stubborn/ aggressive individuals. Although fences are in general more effective for crop protection, due to their severe impact on connectivity we decided against promoting this form of HWC mitigation (Osipova *et al.,* 2018).

From June 2018 a programme was established to systematically protect crops in Enduimet WMA. The project team mobilised community members, provided practical trainings on crop protection and equipped farmers, establishing a number of Village Crop Protection (VCP) teams. Farmers were also encouraged to invest in crop protection by purchasing torches and horns.

A total of 1,027 incidents were recorded in 8 villages over a period of 18 months. Data was collected through smart phones and stored in the KoBoToolbox app (http://www.kobotoolbox.org). Data were elaborated and shared with community members and local authorities to develop data-driven HWC solutions and strategies.

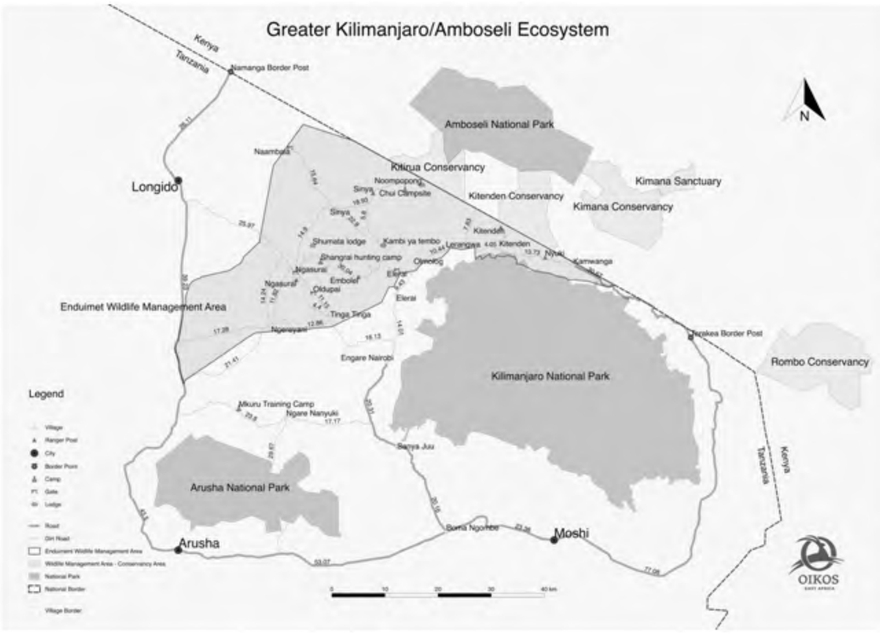

Fig. 1. Map of the Greater Kilimanjaro Ecosystem. HWC data were sourced from Tinga Tinga, Ngereyani, Elerai, Olmolog, Lerangwa, Kitenden, Irkaswa and Kamwanga villages.

RESULTS

The CONNEKT project establishment 25 new VCP teams in8 villages members of EWMA; 73 volunteers were trained in wildlife behaviour, tools management and crop protection techniques. We recorded 1,027 incidents, distributed 38 HWC toolkits and 18 torches,patrolled more than 2,500 acres of crops and secured the 86% of it through the use of toolkits and the efforts of community members. The occurrence of wildlife species raiding crops between June 2018 and November 2019 are presented in Fig.2. Both type and severity of conflict vary among species, elephant (*Loxodonta africana*), similarly to other areas (Hariohay &Røskaft, 2015), is the leading conflict species (57%, n=1027), followed by eland (Taurotragus oryx) (22%, n=1027), zebra (Equus quagga) (14%, n=1027) and buffalo (Syncerus caffer)(6%, n=1027).

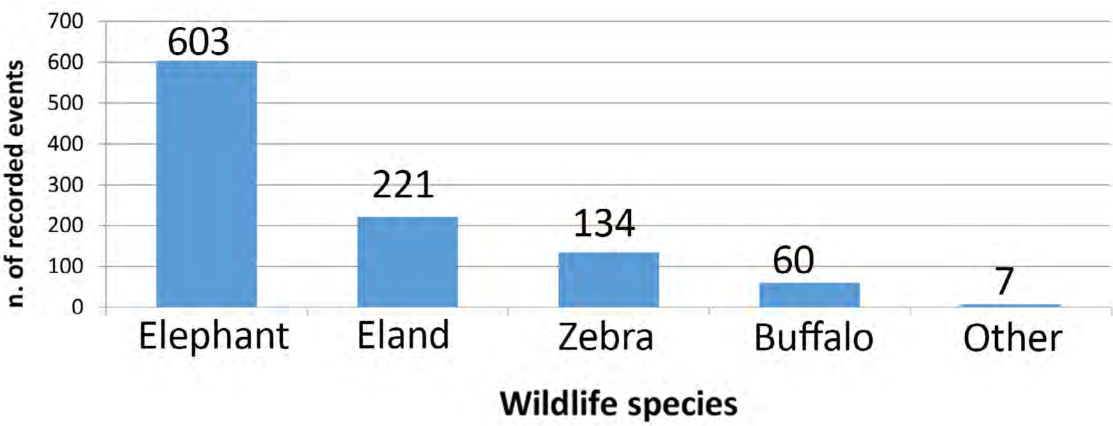

Fig. 2. Total raiders occurrence in the 8 villages bordering the EWMA from June 2018 to November 2019

Torches were reported to be the most effective tool, protecting about 64% of crops when used as a standalone tool, and 84% when used in combination with horns (Fig.3). In 56% of the cases the toolkits saved 100% of the cropped area, in 88% of the cases at least 75%.

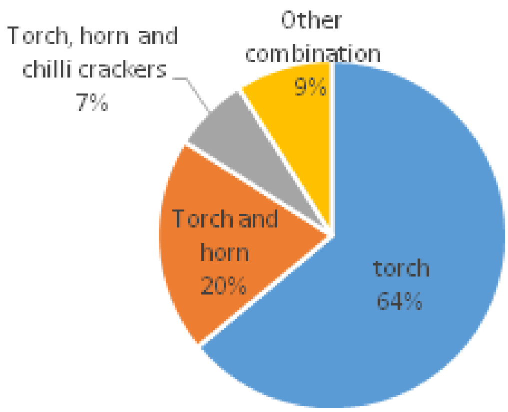

Fig. 3. Effectiveness of the different tools included in the HWC toolkit from June 2018 to November 2019

Expansion of cropland in wildlife areas is the main cause of HWC in EWMA. Records show that affected crops include tomato (34% of wildlife invasions, n = 1,027), maize (29%, n = 1,027) and beans (29%, n = 1,027); a minority of crop invasions were wheat, potatoes, finger millet and banana (Fig.4).

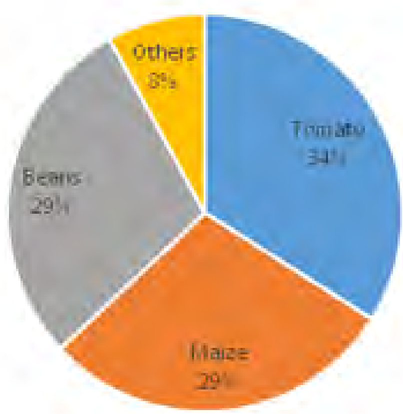

Fig. 4. Distribution of raiding events per crop (June 2018 - November 2019)

RECOMMENDATIONS

Eighteen months of intense monitoring of crop raiding events in 8 villages set in West Kilimanjaro (Tanzania) have shed light on the effectiveness of the application of available, affordable and user-friendly technologies. Data indicated that the combination of a powerful LED (1000 Lumens) torch and a horn provide an effective solution to crop raiding, resolving or preventing crop damage in 84% of crop raiding events. The combination of these two deterrents seems to offer good value for money and it is less traumatic on the wildlife compared to the use of explosives. When a monetary value is associated to the crop saved, the figures clearly show that, although the initial purchase cost is high, investing in the kit would allow the farmers to become independent from donor-supported initiatives in protecting their crops. A further mechanism to strengthen the effectiveness of Village Crop Protection teams is the establishment of by-laws enforcing the active participation of crop farmers in the crop protection initiatives. Increased knowledge of farmers and wildlife officers, as well as a stronger and more structured communication between VCP teams, also contributes to the reduction of losses from coexistence with wildlife.

ACKNOWLEDGEMENTS

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COMMUNICATING SCIENCE FOR EFFECTIVE BIODIVERSITY CONSERVATION

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ABSTRACT

Following two decades of implementing conservation across eastern Africa, we highlight the importance of effective science communication in enabling successful conservation. Targeted, clear and compelling communication can increase engagement and support for research and conservation across community, government and donor levels. We aim to highlight common communication gaps between academia, conservation stakeholders and decision makers, target audiences and the broader public, and explore ways of closing these gaps to improve priority setting, strategy development, impact and sustainability. We outline the process of 'translation' from conveying research findings to different audiences in accessible, compelling and appropriate ways; identifying key points linking research to conservation strategy; identifying relevant target groups to achieving conservation aims; developing communication strategies, messages and materials that engage audiences, and support positive behaviour change. We illustrate the topic using examples from WCS's work across Tanzania in collaboration with stakeholders in Mainland Tanzania and Zanzibar. While acknowledging that science communication, conservation impact and behaviour change are difficult to quantify, examples of reach and impact will be shared. Topics include vulture research and poisoning in Ruaha, Zanzibar Red Colobus research and forest conservation in Unguja, biodiversity research and community conservation in the Southern Highlands, elephant research and corridor protection in Game Reserves, shark and ray research and coastal community awareness. Appropriate communications are essential to close information gaps and foster collaboration between science and conservation practitioners. This can benefit researchers, decision makers, conservation managers and communities. Good communications improve understanding and the protection of Tanzania's unique biodiversity.

Keywords: Biodiversity, Communications, Conservation, Outreach

INTRODUCTION

WCS Tanzania's extensive experience in biodiversity conservation, from research to implementation and monitoring, has demonstrated how effective science communication is essential to inspire action needed to achieve conservation. The involvement, collaboration and support of a range of stakeholders is essential to succeed – from community members and village leaders to district officials, wildlife authority staff, donors, scientists and decision makers. All have different levels of education, time, capacity and experience, and all are influenced by diverse socio-cultural and economic factors and conflicting priorities. Providing and conveying appropriate information in compelling ways is essential to achieving conservation aims. Communicating science well helps increase understanding among stakeholders, enables priority setting, informs conservation strategy, underpins conservation policy development, encourages support (and funding) for research and conservation, helps maximise conservation benefits and ultimately facilitates a sustainable future for biodiversity conservation. Content, language, style, format, medium and distribution methods all need to be considered and tailored to target audiences. Here we outline the process of creating effective science communications using examples of materials produced for WCS and we share insight into their reach and impact.

MATERIALS AND METHODS

WCS's approach is based on science-driven conservation which identifies challenges and solutions from species to landscape level. These are prioritized in order to establish which can best be addressed using communications. Aims are then set and key target groups identified. The most effective messages and mediums are decided upon in consultation with project stakeholders, following which communication outputs are collaboratively developed with the involvement of scientists, writers, designer, photographer, illustrator, editors, translators, community and education team members. Draft materials are field tested where possible to fine-tune content. Once the materials have been distributed and outputs shared, reach is recorded and the impact assessed where feasible, lessons learned, gaps and improvements identified and the approach and outputs revised and developed as necessary.

RESULTS

Fig. 1. Zanzibar red colobus leaflet outlining WCS census findings and species information, designed to convey research and conservation insight to wildlife management authorities, donors, visitors and community members. (Produced in English and Kiswahili). (Davenport *et al,* 2017)

Table 1: Online and print reach recorded for the WCS communications materials featured in Figures 1-5

FIG.	ONLINE REACH	PRINT REACH	
	WCS TZ SOCIAL MEDIA	WCS TANZANIA USAGE	SHARED USAGE
1	3,240 people reached on Facebook, 17 retweets, 49 twitter likes	500 leaflets, 30 large format posters printed. Estimated audience so far 40 wildlife authority staff, 300 tourism stakeholders and community members (distribution ongoing)	Leaflets and posters shared with DRFRNR, Jozani-Chwaka Bay Park authorities, Zanzibar Association of Tourism Investors and individual tourism stakeholders
2	51,267 people reached on Facebook, 30 retweets, 9 twitter likes	Estimated audience 300 vulture awareness day, 200 community education work	300,000 USA school students; pdf copies provided for usage with 8 organisations internationally, also adapted for use in Niassa, Mozambique
3	3,556 people reached on Facebook	250 posters printed, 4 stand-up banners printed. Estimated audience so far 10,500 primary & 15,200 secondary school students, 210,000 community members	Posters shared with conservation partners including TFS, Mount Rungwe Nature Reserve, District & Regional administration, ministries, CEPF
4	413,933 people reached on Facebook, 13 retweets, 19 twitter likes	40 large format posters printed, 4 stand-up banners printed. Estimated audience so far, 200 students & 450 community members (use and distribution ongoing)	Portuguese translation used by WCS Mozambique; pdf files shared for usage with 20 organisations internationally
5	45,323 people reached on Facebook, 95 retweets, 99 twitter likes	NA	NA

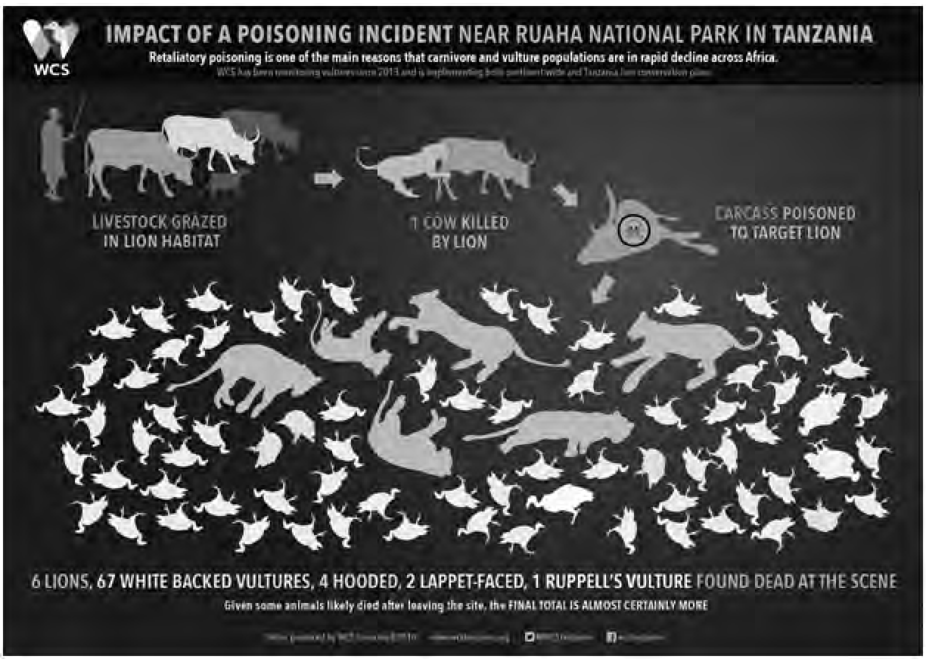

Fig. 2. Infographic poster illustrating data from a poisoning incident, designed to convey the environmental impact to community members, wildlife management authorities, donors and public. (Produced in English, Kiswahili and Portuguese)

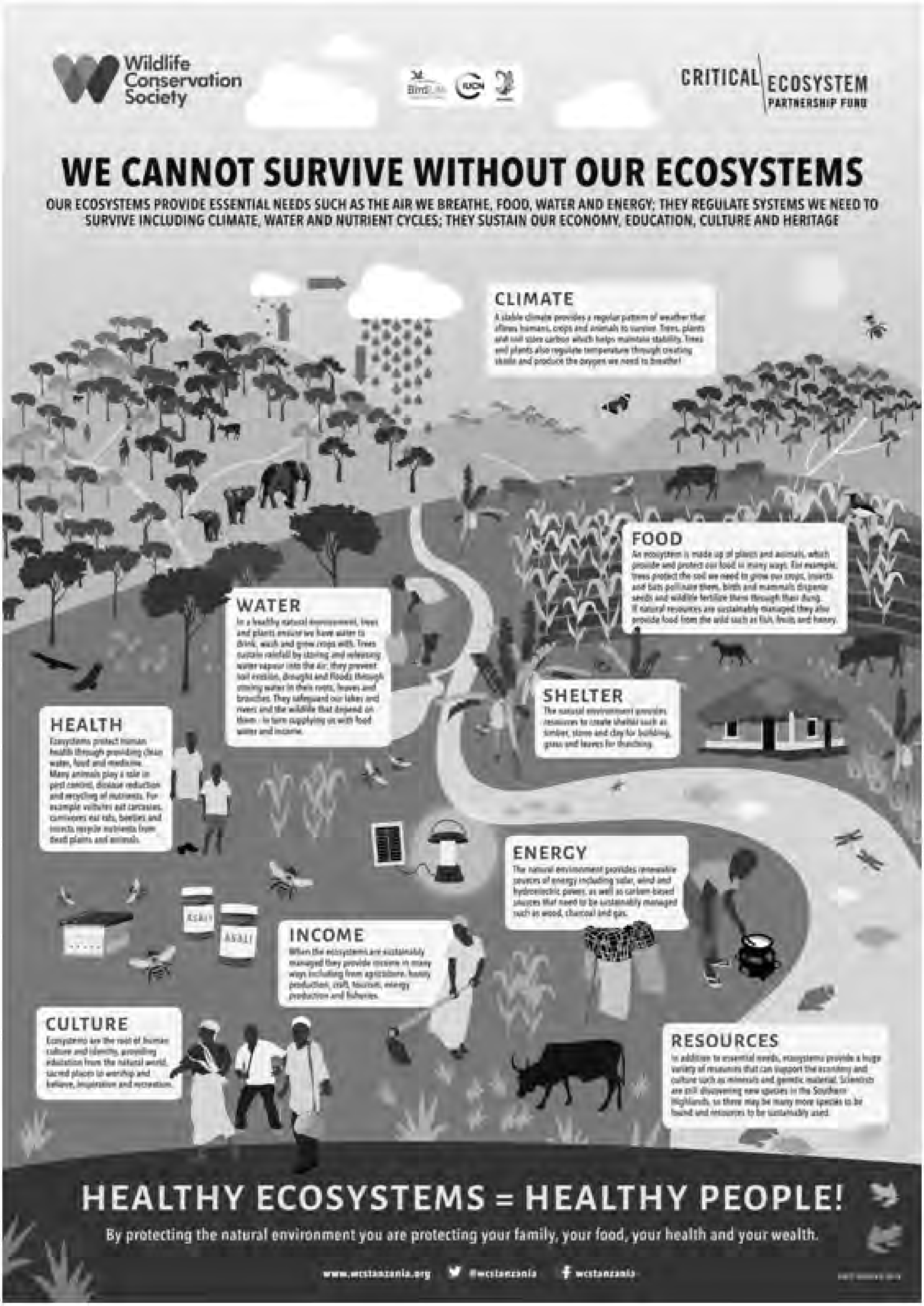

Fig. 3. Educational poster illustrating ecosystem services to community members and conservation stakeholders. (Produced in English and Kiswahili)

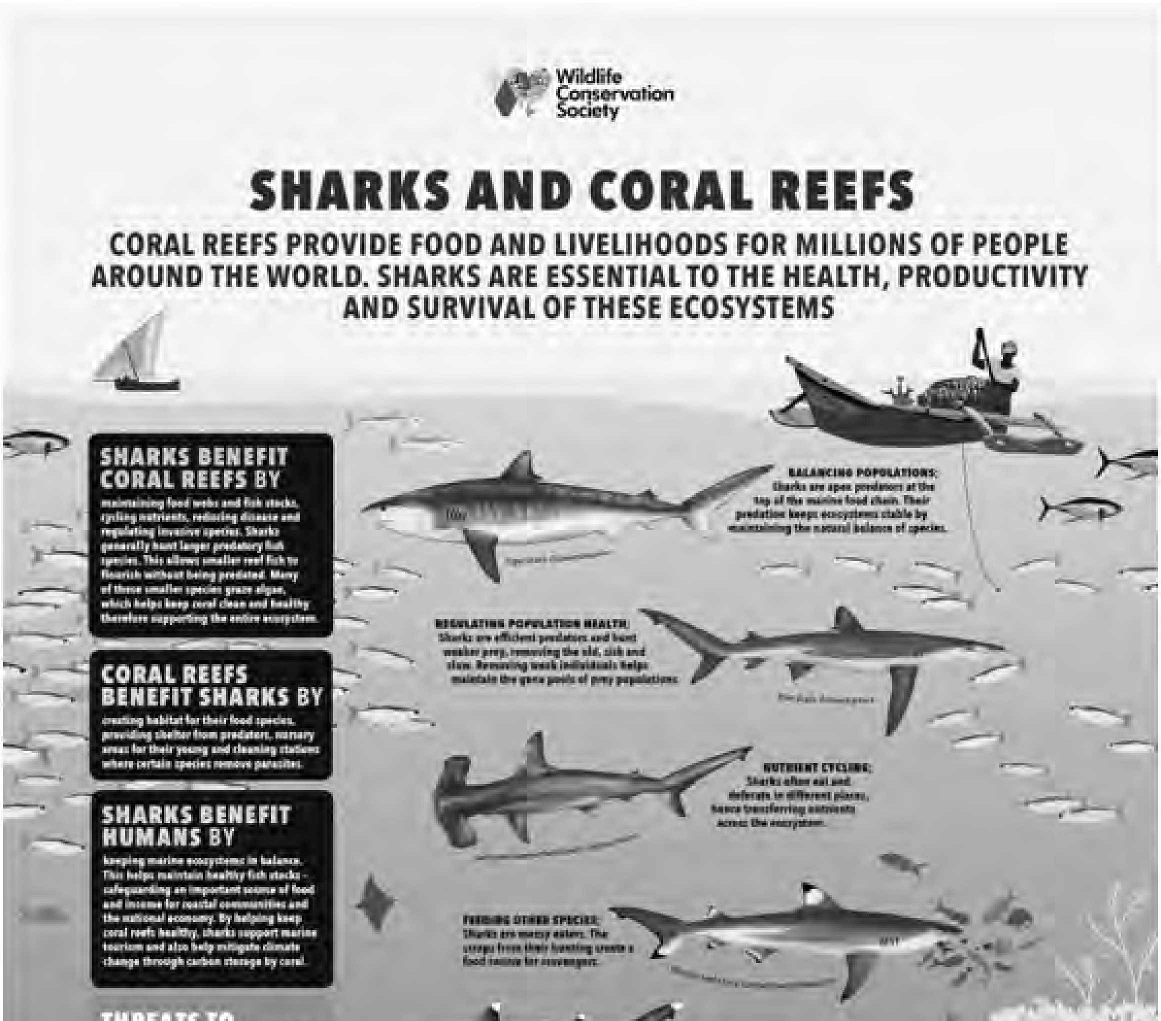

Fig. 4. Educational poster illustrating the ecology of sharks and reefs to community members and conservation stakeholders. (Produced in English, Kiswahili and Portuguese)

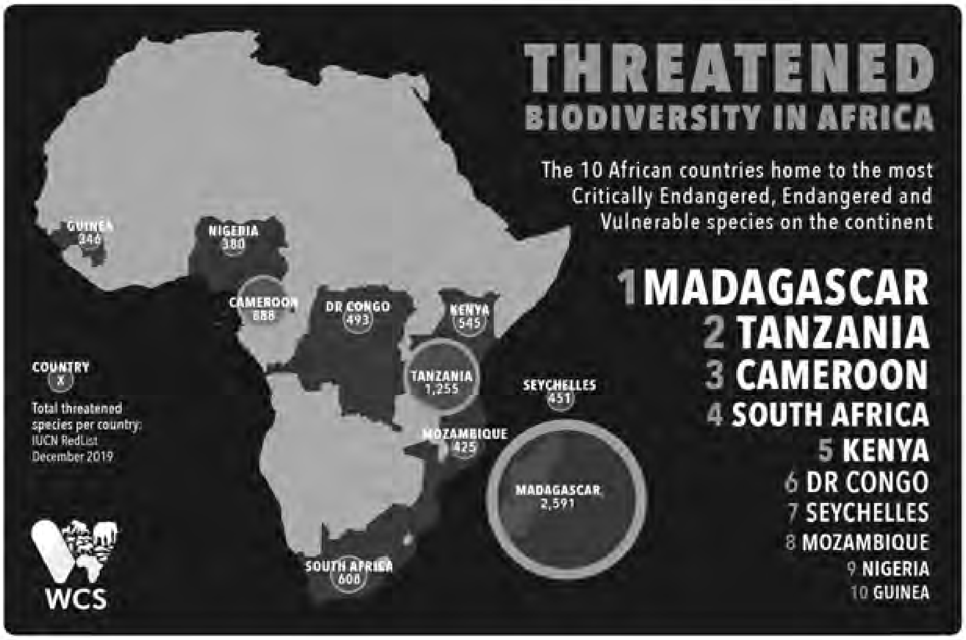

Fig. 5. Infographic based on IUCN RedList data to illustrate key countries for biodiversity conservation to policy makers, conservation stakeholders and donors.

DISCUSSION

The nature and distribution of materials designed and used by WCS means it can be challenging to accurately quantify reach or impact, especially given most are in constant use and review. However, Table 1 provides some insight based on figures provided by online analytics, print material distribution and audience numbers.

These numbers demonstrate that the communication materials are reaching a significant number of stakeholders, across a broad demographic and geographic range. Given the relatively low cost of producing such materials compared to many conservation interventions, the positive impact in relation to financial outlay is considerable. The educational stand-up banners for example, are used on a weekly basis for several years, meaning they are each likely to be seen by around half a million people, while the production cost (time and printing) amounts to around 300 USD.

While we have not had the resources to do detailed research into learning outcomes from specific communication materials, ongoing interactions with stakeholders and community members have demonstrated much higher awareness levels of species and habitat conservation importance as a result of their usage in education efforts. Some materials have also been instrumental in obtaining funding for ongoing research and conservation. It is notoriously difficult to quantify behaviour change, but as above, ongoing involvement with project participants and conservation partners shows that education and communication materials contribute considerably to project understanding and engagement.

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The features communication materials and more can be seen online on https://www.facebook.com/wcstanzania/

VALUATION OF NATURAL RESOURCES: CAN CHOICE EXPERIMENTAL METHOD BE SUSTAINED IN TANZANIA? A THEORETICAL REVIEW

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ABSTRACT

This paper, through a review of various literatures, has attempted to show the link between physical change to the environment (for example, damage) and its expression in terms of willingness-to-pay (WTP) and willingness-to-accept (WTA) compensation. The applicability of non-market valuation techniques have now been widely accepted as an effective tool for public decision making in developed countries. Valuation is dependent on contingent upon a hypothetical situation or scenario whereby a sample of the population is interviewed and individuals are asked to state their maximum WTP (or minimum WTA compensation) for an increase (decrease) in the level of environmental quantity or quality. To this end, in contrast, for choice experiment,the individuals are given a hypothetical setting and asked to choose their preferred alternative among several alternatives in a choice set. The choice experiment is a multi-attribute stated preference elicitation technique because each alternative is described by a number of attributes or characteristics. A monetary value is included as one of the attributes, along with other attributes of importance, when describing the profile of the alternative presented. Thus, when individuals make their choice, they implicitly make trade-offs between the levels of the attributes in the different alternatives presented in a choice set. Furthermore, the choice experiment method avoids many of the problems associated with the contingent valuation method. Therefore, identification and evaluation of the different attributes of a damaged good is required in order to design the preferred restoration of a project. Choice experiments are especially well suited for this purpose. As to what extent the choice experiment method is applicable in Tanzania remains an issue of concern.

Keywords: Choice experiment, non-market goods, natural resources, valuation, willingness-to-pay, willingness-to-accept.

INTRODUCTION

The interest in valuation techniques for non-marketed goods and services arises partly from the concern that efforts to protect and improve the environment should be cost-effective and increase human well-being. Valuation provides a link between physical change to the environment (for example, damage) and its expression in terms of willingness-to-pay (WTP) and willingness-to-accept (WTA) compensation.

The applicability of non-market valuation techniques have now been widely accepted as an effective tool for public decision making in developed countries. Certain techniques are been initiated even in the private sector, most notably the choice experiment method (Bennettand Birol, 2010). Stated preference method for valuation assesses the value of non-marketed goods by using individuals' stated behavior in a hypothetical setting. The contingent valuation Method (CVM), elicits individuals' preferences, in monetary terms, for changes in the quantity or quality of a non-market environmental resource. Valuation is dependent on contingent upon a hypothetical situation or scenario whereby a sample of the population is interviewed and individuals are asked to state their maximum WTP (or minimum WTA compensation) for an increase (decrease) in the level of environmental quantity or quality. In contrast, for choice experiment, the individuals are given a hypothetical setting and asked to choose their preferred alternative among several alternatives in a choice set. The choice experiment is a multi-attribute stated preference elicitation technique because each alternative is described by a number of attributes or characteristics. A monetary value is included as one of the attributes, along with other attributes of importance, when describing the profile of the alternative presented. Thus, when individuals make their choice, they implicitly make trade-offs between the levels of the attributes in the different alternatives presented in a choice set (Alpizar *et al*., 2001). Furthermore, the choice experiment method avoids many of the problems associated with the contingent valuation method such as information bias, design bias (starting point bias and vehicle bias), hypothetical bias, yes-saying bias, strategic bias (free-riding), substitutes it and embedding effects (Bateman *et al*., 2003; Hanley *et al.*, 1998; B oxall *et al.*,1996).

Application of choice experiment technique has become more frequent in other areas of economics as well. Recently the aim of damage assessment in litigation shifted from monetary compensation to resource compensation. Therefore identification and evaluation of the different attributes of a damaged good is required in order to design the preferred restoration project (Adamowicz *et.al.*,1998; Layton & Brown,1998). Choice experiments are especially well suited for this purpose, and one could expect this method to be a central part of future litigation processes involving non-market goods.

The main objective of this paper is to present a theoretical analysis on how choice experiment technique is applied in valuing non-marketed goods and services in contrasting with other techniques such as contingent valuation techniques. Specifically the paper seeks to show how individuals are given a hypothetical setting and asked to choose their preferred alternative among several alternatives in a choice set. To this end, each alternative is described by a number of attributes or characteristics.

METHODOLOGICAL ISSUES IN CHOICE EXPERIMENT

This is a review paper where choice experiment on willingness to pay and or to accept was reviewed. In choice experiment as well as in a contingent valuation method survey, the economic model is intrinsically linked to the statistical model. The economic model is the basis of the analysis, affects the design of the survey and the analysis of the data. Realization of choice experiment is best viewed as an integrated and cyclical process that starts with an economic model describing the issue to analyze. It is then continually revised as new information from the experimental design, the statistical model, focus groups and pilot studies, etc. Generally, the choice experiment approach was initially developed by Louviere & Hensher (1982) and Louviereand Woodworth (1983), and isoneoptionina family of empirical stated preference approaches known as choice modelling. Respondents area sked to choose between alternative goods, defined in terms of their attributes. The choice experiment approach shares a common theoretical framework with other environmental valuation approaches in the random utility model. According to this framework, the indirect utility function for each respondent (Ui) can be decomposed into two parts: a deterministic element (V), which is typically specified as a linear index of the attributes (X) of the j different alternatives in the choice set, and a stochastic element (e), which represents unobservable influences on individual choice:

$$U_{ij} = V_{ij}(X_{ij}) + e_{ij} = bX_{ij} + e_{ij} \ldots. (1)$$

The probability that any particular respondent prefers option"g"in the choice set to any alternative option "h", can be expressed as the probability that the utility associated with option"g"exceeds that associated with all other options:

$$P[(U_{ig} > U_{ih})\forall h \neq g] = P[(V_{ig} - V_{ih}) > (e_{ih} - e_{ig})] \,.. \,(2)$$

In order to derive an explicit expression for this probability, it is necessary to know the distribution of the error terms. A typical assumption is that they are independently and identically distributed with an extreme-value (Weibull) distribution:

$$P(e_{ij} \leq t) = F(t) = \exp(-\exp(-t)) \,.. \,(3)$$

The above distribution of the error term implies that the probability of any particular alternative g being chosen as the most preferred can be expressed in terms of the logistic distribution (McFadden, 1973) stated in equation (4). This specification is known as the conditional logit model:

$$P(U_{ig} > U_{ih}, \forall h \neq g) = \frac{\exp(\mu V_{ig})}{\sum_j \exp(\mu V_{ij})} \ldots.. (4)$$

Where is a scale parameter, inversely proportional to the standard deviation of the error distribution. This parameter cannot be separately identified and is therefore typically assumed to be one. This model can be estimated by conventional maximum likelihood procedures, with the respective log-likelihood functions stated in equation (5) below, where is an indicator variable which takes a value of one if respondent j chose option I and zero otherwise:

$$\log L = \sum_{j=1}^{N} \sum_{j=1}^{J} y_{ij} \log[\frac{\exp(V_{ij})}{\sum_{j=1}^{J} \exp(V_{ij})}] \ldots\ldots (5)$$

Once the parameter estimates have been obtained, a willingness-to-pay (WTP) compensating variation welfare measure that conforms to demand theory can be derived using the formula given by (6)(Parsons & Kealy, 1992) where represents the utility of the initial state and represents the utility of the alternative state. The coefficient by gives the marginal utility of income and is the coefficient of the cost

$$WTP = b_y^{-1} \ln \left\{ \frac{\sum_i \exp(V_i^1)}{\sum_i \exp(V_i^0)} \right\} \ldots\ldots. (6)$$

It is straight forward to show, for the linear utility index specified in (1), that the value of a marginal change in any of the attributes can be expressed as the ratio of coefficients given in equation (7) where bC is the coefficient to any of the attributes. These ratios are often known as implicit prices:

$$WTP = \frac{-b_C}{b_y} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

An important implication of this specification is that selections from the choice set must obey the "independence from irrelevant alternatives" (IIA) property. This property states that the relative probabilities of two options being selected are unaffected by the introduction or removal of other alternatives. This property follows from the independence of the Weibull error terms across the different options contained in the choice set. If a violation of the IIA hypothesis is observed, then more complex statistical models are necessary that relax some of the assumptions used. These, to mention a few, include the multinomial probit (Hausman & Wise, 1978), the random parameters logit model (Train, 1998) and the heterogeneous extreme valuelogit (Bhat, 1995; Allenby & Ginter,1995).

Table 1. Proceeding that are followed with choice experiments

Stage	Description
Selection of attributes	Selection of relevant attributes of the good to be valued. This is usually done through literature reviews, focus groupd is cussions or direct questioning. Sometimes they may beself-evident because of the nature of the problem. A monetary cost is usually one of the attributes to allow the estimation of WTP.
Assignment of levels	The attribute levels should be realistic and span the range over which we expect respondents to have preferences, and/or practically-achievable levels.
Choice of experimental design	Statistical design theory is used to combine the levels of the attributes into a numberof alternative environmental scenarios or profiles to be presented to respondents. *Complete factorial designs* allow the estimation of the full effects of the attributes upon choices:that includes the effects ofeachof the individual attributes presented (maineffects) and the extent to which behavior is connectedwith variations in the combinationof different attribute offered (interactions).
Construction of choice sets	The profiles identified bythe experimentaldesign are then grouped into choice sets to be presented to respondents. Profiles can be presented individually, in pairs or in groups.
Measurementof preferences	Choice of survey procedure,and conductof survey.

Source: Bateman *et al*. (2003)

RESULTS OF THE CHOICE EXPERIMENTS

Correct specifications of the choice set from which individuals make their choice is critical to the successful conduct of choice experiment. The end results of the choice experiment seeks:

- To maximize attribute and task plausibility and realism from the respondents' perspective;
- To identify and use attributes and choice alternatives that are relevant and determinant from the respondents' perspective;
- To create and implement meaningful and acceptable tasks;
- To balance task complexity with realism and response reliability and validity;
- To identify attributes, choice alternatives and tasks that are relevant and determinant from a client's or user's perspective; and to develop and implement tasks with appropriate incentive properties.

The alternatives that are presented to the respondents can either be labeled or unlabeled instance, the base scenario or the status quo may be labeled as the current scenario and the alternatives as the improved scenarios. The number of levels for the attributes that a researcher can use depends on:

- The number of levels needed to explain the hypothetical scenario;
- The size of the experimental design that one can afford;
- The need to specify non-linear attribute effects.

The choice sets which are presented to the respondent scary a wealth of information that must be assimilated and acted upon. Thus care must betaken so that the amount of information does not exceed the respondents' capability in answering them. On the other hand, sufficient variations to the alternatives presented to there respondents must be provided in order to establish statistically the impact of attribute levels on the choices made.

The focus group sessions is the best way to introduce and explain the task of making a succession of choices from a series of choice sets. According to Layton & Brown (2000), choosing repeatedly is not necessarily a behavior that could be regarded as obvious for all goods. When it comes to say, choices made for recreation,it is clear that choosing as it in a choice set does not preclude choosing another site given different circumstances. However, in the case of public goods, such repeated choices might require further justification in the experiment.

CAN CHOICE EXPERIMENTS BE APPLICABLE IN TANZANIA?

Valuing non-marketed environmental resources in Tanzania is still a major challenge. But it is a model that should be applied in Tanzania since environmental resources are declining at an increasing rates. In fact non of the techniques of valuing non-marketed environmental resources that is applicable in Tanzania. Even the contingent valuation technique which is simple to apply does do exist in Tanzania. Contingent valuation technique as a counterpart of choice experiment technique is a study that involves interviews with the participants that can be undertaken as face-to-face, mail or telephone based.

The typical contingent valuation method study starts with informing the participants about the environmental resource in focus (e.g. air quality) along with information about the proposed change in the environmental resource and the procedure to be used to finance the proposed changeling the environmental resource. This information is provided in order to familiarize the respondents about the change to be evaluated such that the possibility for valid and reliable answers is enhanced.

On the basis of this information the respondents are asked about willingness to pay (WTP). Usually, a series of follow-up questions are included in order to confirm the given WTP [or willingness to accept-(WTA)] as well as provision of socio-economic back ground information (gender, age, employment, income). This background information can be utilized to examine their relationship to WTP, e.g. the extent to which willingness to pay depends on income could be tested. To this end, non of the techniques that is currently under application, either contingent valuation nor choice of experiment technique has been applied in Tanzania.

Since Tanzania strives to attain middle income country status by 2025 through an industrial led-economic growth, valuing non-marketed environmental resources cannot be left unattended to. This is because any economic growth, at least in developing economies, is associated with trade offs between economic growth and deterioration of environmental resources such as air, forests, and water. To this end, Tanzanians should be made aware on how to value such resources whose market value are not known before any big project that affect their existence is launched.

CONCLUSION

Choice experiments are samples of choice sets or choice scenarios drawn from the universe of all possible choice sets. The samples are drawn a priori according to statistical design principles in such away that the over all choice experiment consists of a set of choice sets that satisfies certain estimation requirements of certain forms of choice models. And as such choice experiments should possess the following elements:

- A set of fixed choice options that have explicit names;
- A set of attributes that describe potential differences in the choice options;
- A set of levels or values assigned to each attribute of each choice options to represent arrange of variation in that attribute appropriate to the research objectives of a particular study;
- A sample of subjects that evaluate all or a subset of the choice sets in the total experiment and chooses one of the possible options available to be chosen in each set.

Establishing such elements that are required by the choice experiment renders the application of this technique weaker not only in Tanzania but also in most of the developing economies. But then efforts should be put in place to adopt this technique given the fact that non-marketed environmental resources ought to have their monetary values placed on them.

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CHALLENGES OF HIGH PARASITE INFESTATION IN CONSERVING HERBIVORES IN SMALL PROTECTED AREAS: A CASE OF RUBONDO AND SAANANE ISLANDS NATIONAL PARKS, LAKE VICTORIA, TANZANIA

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ABSTRACT

In ideal situations, wild herbivores range widely to minimize risk of predation and reduce level of parasites infestation. In isolated small protected areas, herbivores face big challenge on how to minimise parasites infestation on rangelands. At Rubondo and Saanane Islands National Parks (RINP & SINP) in Lake Victoria, herbivores have been exhibiting poor body condition with noticeable mortalities. In Rubondo Island the common antelopes are sitatunga (*Tragelaphus spekii*) and bushbuck (*Tragelaphus scriptus*), while at Saanane Island the main herbivores are impala (*Aepyceros melampas*), zebra (*Equus burchelli*), klipspringer (*Oreotragus oreotragus*) and wildebeest (*Connochaetes taurinus*). Investigations were conducted to establish the cause of poor body conditions and observed mortalities. The findings revealed that at RINP the cause of poor body conditions and mortality for bushbuck and sitatunga was ticks (*Amblyomma variegatum*, *Rhepicephalus appendiculatus*) and lice (*Damalinia sp.*) infestation, with the former causing theileriosis apart from trauma, stress and blood loss, and secondary bacterial infection leading to severe bronchopneumonia. At SINP the cause of poor body conditions and observed mortality for impala was heavy Strongyle worm load (2993±1382 with range of 1000-4500 epg) and high tick infestation (*Amblyomma marmerium*, *Rhepicephalus evertsi*, *Rh. appendiculatus*) and starvation. For zebra it was tick infestation (*Rh. evertsi*), which subjected them to severe bronchopneumonia from unconfirmed secondary infection. Small sizedrangelands in the two protected areas are the underlying cause of high parasites infestation. Introduction of parasites' control programme in both islands and forage supplementation or minimizing number of herbivore units to ecologically acceptable level at SINP, and cutting tall grass at RINP is recommended to enhance performance of herbivores on the isolated small protected areas.

Keywords: Conservation, small protected areas, health issues

INTRODUCTION

Wild animals require large home ranges in order to avoid excessive parasite infestations, both ecto-parasites and endo-parasites. Confinement of wild animals inside small and isolated areas requires routine manipulation in order to control ecto-endoparasites such as ticks and gastro-intestinal parasites (nematodes, cestodes and trematodes). Level of trace elements in soils determines the forage quality both for herbivores and carnivores, and indirectly has implication to the level of body immunity against parasite infestation. Rangelands in small sized protected areas are prone to high contamination and infestation with ecto-parasites and endo-parasites if some interventions are not instituted. High level of parasite load entails that the frequency of host-parasite encounter and infestation is high. For nutritionally stressed animals, it can lead to serious health problems with fatal consequences (Fyumagwa *et al*., 2013).

Rubondo Island National Park (RINP) and Saanane Island National Park (SINP) form two island populations of wild herbivores. A significant number of sitatunga (*Tragelaphus spekii*) and bushbuck (*Tragelaphus scriptus*) deaths occurred in RINP during the past two decades. Management response to contain the problem, different approaches were attempted to determine causative factors that are associated with the antelopes' deaths (Kiwango, 2003; Mlengeya *et al*., 2008; Lyaruu & Mgendi, 2013). Previous studies implicated the deaths to heavy load of ecto-parasites, especially ticks and lice, at different levels of infestation as one of the main factors. Among tick species collected from sick animals included *Amblyoma variegatum* and *Rhipicephalus appendiculatus*. Also haemoparasites such as Trypanosoma sp., were found in blood samples (Mlengeya *et al*., 2008). A study by Lyaruu & Mgendi (2013) revealed high levels of biting lice and tick infestations on sitatunga and bushbucks in RINP. Although the findings provide plausible causes of deaths, further investigation was necessary to establish the etiological agent or whether multiple factors/ agents may be responsible for the deaths.

Saanane Island National Park was established in 1964 as a zoo, with an area of about 2.8 square kilometres. The zoo was established and managed by the Mwanza District Council up to 1991 when it was upgraded to a game reserve under the Wildlife Division (WD). The small reserve had several captive animals that included lions (*Panthera leo*), leopard (*Panthera pardus*), chimpanzees (*Pan troglodytes*), crocodiles (*Crocodila nilotica*) and elephant (*Loxodonta africana*). Also it had free ranging herbivores including plains zebra (*Equus burchelli*), dikdik (*Madoqua kirkii*) and impala (*Aepyceros melampas*) and a high diversity of birds. Due to economic recession, the Wildlife Division did not have sufficient resources to continue managing the reserve, including replacement of animals when they die from natural causes or from diseases. In understanding the high demand for the recreational site especially for game viewing among Mwanza city residents and its suburbs, the government decided to transfer the Management of the island to Tanzania National Parks (TANAPA) in 2006. The island remained as a game sanctuary under TANAPA until 2013, when it was upgraded into a national park with the aim of reviving the recreational site for both local and foreign tourists and for educational purposes. In order to revive the game viewing activities it was important to embark on introducing more animals and ornamental large birds. The aim of the investigations was to establish the cause of poor body conditions and observed mortalities.

MATERIALS AND METHODS

Study areas

Rubondo Island National Park (RINP)

The RINP is a protected area of about 456.8 km^2 situated at 2°18'10.3 S and 31°51' 26.9" E in Lake Victoria, and the island was gazetted as protected area in 1977. The habitat in RINP is predominantly tropical forest with patches of grassland. The survey was conducted along the existing road network starting at Kageye area (Head office of RINP), Kageye- Mlaga route, Mlaga- Lukukuru route and Kageye- Kasenye route (Fig. 1). The island has few animal species including elephants (*Loxodonta africana*), giraffe (*Giraffa camelopardalis*), bushbuck, sitatunga, vervet monkeys (*Chlorocebus pygerythrus*), chimpanzee (Pan troglodytes), bush pigs (*Potamochoerus larvatus*) and more than 100 birds species. Most of the mammal species were introduced in the 1970s'(Marttila, 2011)(Plate 1).

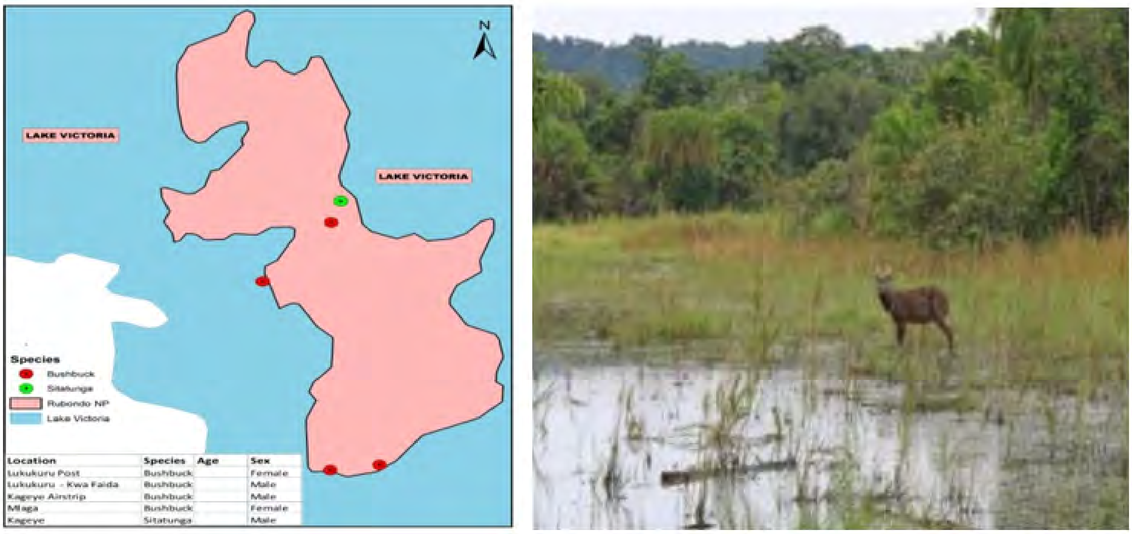


Fig. 1. Sketch map of RINP showing sampling locations for bushbuck and sitatunga (left) and habitat type (Plate 1 right)

At the time when management of Saanane Island was transferred to TANAPA, impala (*Aepyceros melampas*), velvet monkey (*Chlorocebus pygerythrus*) and Tortoises were the mainterrestrial animals in the island. However, following establishment of the SINP, TANAPA directed much effort and resources to revamp the sanctuary into an attractive national park and embarked on introducing wild animals species including plainszebra (*Equus burchelli*), wildebeest (*Connochaetes taurinus*), klipspringer (*Oreotragus oreotragus*), dikdik (*Madoqua kirkii*), lions (*Panthera leo*), peacock (Pavo cristatus), Egyptian geese (*Alopochen aegyptiaca*) and helmeted guinea fowls (*Numida meleagris*). In 2018, there was a disease problem that affected zebra, with 60% mortality (3 out of 5 individuals). The cause of the disease was not established but it was tentatively suggested that nutritional stress and heavy tick infestation predisposed them to an unidentified viral disease, which caused the observed pathological manifestation. During this time, impala, although is the dominant species in terms of population size, had no noticeable mortality but their body conditions were poor. From July 2019, impala were reported to be in poor condition and recorded mortality which continued to August 2019. Wildlife veterinarians and ecologists were requested to investigate the problem and advise the Management of SINP on how to improve the health conditions of the affected animals in the park.

Investigation on Sitatunga and bushbuck mortality

A significant number of sitatunga (*Tragelaphus spekii*) and bushbuck (*Tragelaphus scriptus*) deaths have been occurring in Rubondo Island National Park (RINP) during the past two decades. In response to contain the situation, different approaches have been attempted to determine the factors that are associated with the deaths (Kiwango, 2003; Mlengeya *et al*., 2008; Lyaruu & Mgendi, 2013).

Plains zebra

The diseases problem was reported for the first time in plains zebra on 18th July 2018, when two zebras were reported to have died. Due to absence of wildlife health expert to monitor the animals on daily basis, there were no report of the poor performance of the animals until when the two animals died. Unfortunately, due to few number of wildlife veterinarians, none of TANAPA or TAWIRI veterinarians were available in Serengeti at the time of reported death to go and conduct the investigation on the possible cause of mortality. Therefore, veterinarians from Tanzania Veterinary Laboratory Agency (TVLA), Lake Zone were contacted and performed the necropsy in collaboration with the TANAPA technician and submitted the report to the authorities.

On 24th July 2018 a second report was send to TAWIRI informing that a third female zebra has died and a fourth one was seriously sick. This animal was reported to have shown signs of weakness on the day when she died and was pregnant and it had signs of abortion before death. During the report of the third death, they reported that another female zebra was exhibiting signs of weakness, not feeding well and had difficulty breathing. The remaining two adult zebras, one female and one male were examined from a distance and noted that the female zebra was exhibiting signs of difficult breathing, in coordination, was not feeding well and was reluctant to respond to external stimuli as a health zebra could do compared to the male zebra. Both zebras had high tick infestation, which were vividly seen from a distance and even questing ticks were observed on grass.

Impala

The investigation began with taking a history from the park ecologist and his assistants, who informed the team that up to 19th July 2019, six impala had died from disease problem and one from suspected snake bite. History taking was followed by field visit in the park to have a general observation of the animals and their habitat in order to come up with provisional diagnosis. Behavior of impala was closely observed including feeding and dung texture. Dung samples were collected from impala with symptoms of diarrhea and from those that had normal dropping for laboratory examination to determine for worm load.

Laboratory analyses

Samples for laboratory investigation included ecto-parasites (ticks & lice), blood samples and herbivores' dung samples from both RINP & SINP respectively. For dead animals postmortem examination was performed for observation of pathological changes and provide a provisional diagnosis for cause of mortality and sample collection for laboratory examination as described in subsequent paragraph.

Samples collected at RINP were analysed at RINP and Serengeti Wildlife Veterinary Laboratories (SWRC), and samples from SINP were analysed at Tanzania Veterinary Laboratory Agency (TVLA- Mwanza) and SWRC respectively. Stereo microscope was used to identify ecto-parasites with the aid of identification guidebook, while light microscope was used to identify endo-parasites from dung samples following sedimentation test, and McMaster was used to establish egg count per gram (epg) of dung samples. Giemsa stained blood smears were examined under light microscope for blood parasites as shown in different plates on result section.

RESULTS

Health status of animals at RINP

In general most of the animals which were encountered in the surveyed places were in good body conditions. Some individuals in the herds of sitatunga and bushbucks were observed with fair body conditions especially at Kageye, Mlaga and Lukukuru ranger posts (Table 1). Apparently animals observed from a distance with good body conditions were also found with moderate ecto-parasites (ticks and lice) infestation. Most animals with ecto-parasites infestation were seen flipping their tails continuously as an effort to get rid of the parasites and relieve from itching effects.

Table 1: Sitatunga and Bushbuck observed or assessed in RINP in March 2018

	Age			Sex			Health status			
Species	**Adult**	**Sub-adult**	**Juvenile**	**Male**	**Female**	**Unknown**	**Good**	**Fair**	**Dead**	**Total**
Bushbuck	49	19	8	29	44	3	73	2	1	76
Sitatunga	21	1	1	9	13	1	19	4	0	23

Postmortem examinations

Bushbuck

The significant finding for bushbuck from external observation were emaciation, sunken eyes and heavy infestation with ecto-parasites including ticks and lice. In the internal organs the significant findings were lung congestion, frothing in bronchioles, a cyst on the tip of medial left lobe, lung adhesion on pleural surface, excessive fluid in thoracic cavity, liver congestion, petechial hemorrhages in spleen, enlarged superficial lymph nodes and in abomasum there were cigar burn ulcers (Plate 3&4).

Plate 3. A male and female bushbuck found dead with poor body condition and heavily infested with lice and ticks

Plate 4. Generalized lung congestion, adhesion of the right cranial lobe, a cyst on medial left lobe, a cigar burn ulcer on abomasum and petechial hemorrhages on spleen

Sitatunga

Male sitatunga was in fair body condition and was immobilized for routine examination and sampling, unfortunately, it died from aspiration pneumonia. Therefore, the postmortem examination was performed to confirm for the cause of death and collection of samples for subsequent laboratory examination. Externally the body was heavily infested with lice and ticks. The superficial lymph nodes were enlarged similar to what was observed in bushbucks (Plate5).

Plate 5. Sitatunga in fair body condition but with heavy ecto-parasites load

Ecto-parasites identification

Both captured bushbuck and sitatunga were heavily infested with ectoparasites and the predominant identified ecto-parasites included lice and ticks. Laboratory examination using stereo microscopy established the genera of ecto-parasites to be biting lice-Damalinia sp., and ticks - Amblyomma variegatum & Rhipicephalus appendiculatus (Plate 6 & Table 2). However, because collection of ecto-parasites did not aim at removing all the observed parasites on the animal body it is likely that some of the tick species were missed and there are more tick species on these antelopes than is reported here as was reported in previous studies.

Plate 6. Ecto-parasites including lice and ticks collected on bushbuck and sitatunga

Table 2: Ecto-parasites identified from handled antelopes in various locations

S/N	Location	Coordinates Easting	Coordinates Northing	Antelope species	Ectoparasites
1	Kageye airstrip	36M 0371629	UTM9745156	Bushbuck-male	Biting lice (*Damalinia* sp), ticks (*Amblyomma variegatum, Rhipicephalus appendiculatus*)
2	Kageye HQ	36M 0372076	UTM 9746587	Sitatunga-male	Lice (*Damalinia* sp), ticks (*Amblyomma variegatum, Rhipicephalus appendiculatus*)
3	Lukukuru-post1	36M 0371664	UTM 9727758	Bushbuck-female	Lice (*Damalinia* sp), ticks (*Amblyomma variegatum, Rhipicephalus appendiculatus*)
4	Lukukuru-kwa faida 2	36M 0373898	UTM 9727887	Bushbuck-male	Lice (*Damalinia* sp), ticks (*Amblyomma variegatum, Rhipicephalus appendiculatus*)
5	Mlaga	36M 0368418	UTM 9741241	Bushbuck – female	Lice (*Damalinia* sp), ticks (*Amblyomma variegatum, Rhipicephalus appendiculatus*)

Microscopic examination

The microscopic examination was for lymph node impression smears, blood smears and lung impression smears. Blood and lymph node smears were stained with Giemsa stain for protozoa and the lung impression smears were stained with Gram stain for bacterial examination.

Lymph node impression smears

Lymph node smears from bushbucks and sitatunga had many macroschizonts suggesting infection with Theileria sp., from ticks (Plate 7). Theileriosis is a number one killer for cattle in central and eastern Africa, therefore, presence of these protozoa in antelopes suggest that theileriosis might be contributing significantly to the frequent reported antelope mortality in RINP.

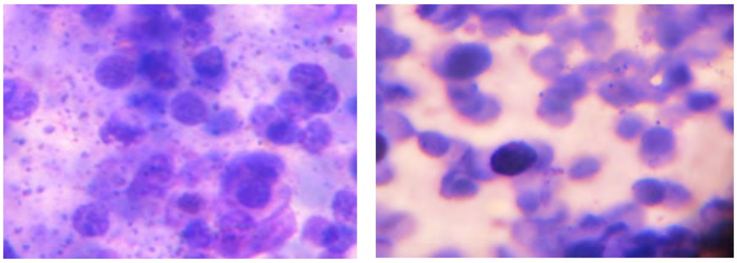


Plate 7. *Theileria sp*., macroschizonts in lymph node smears from bushbuck (left) and sitatunga (right)

External examination of a dead Plains zebra

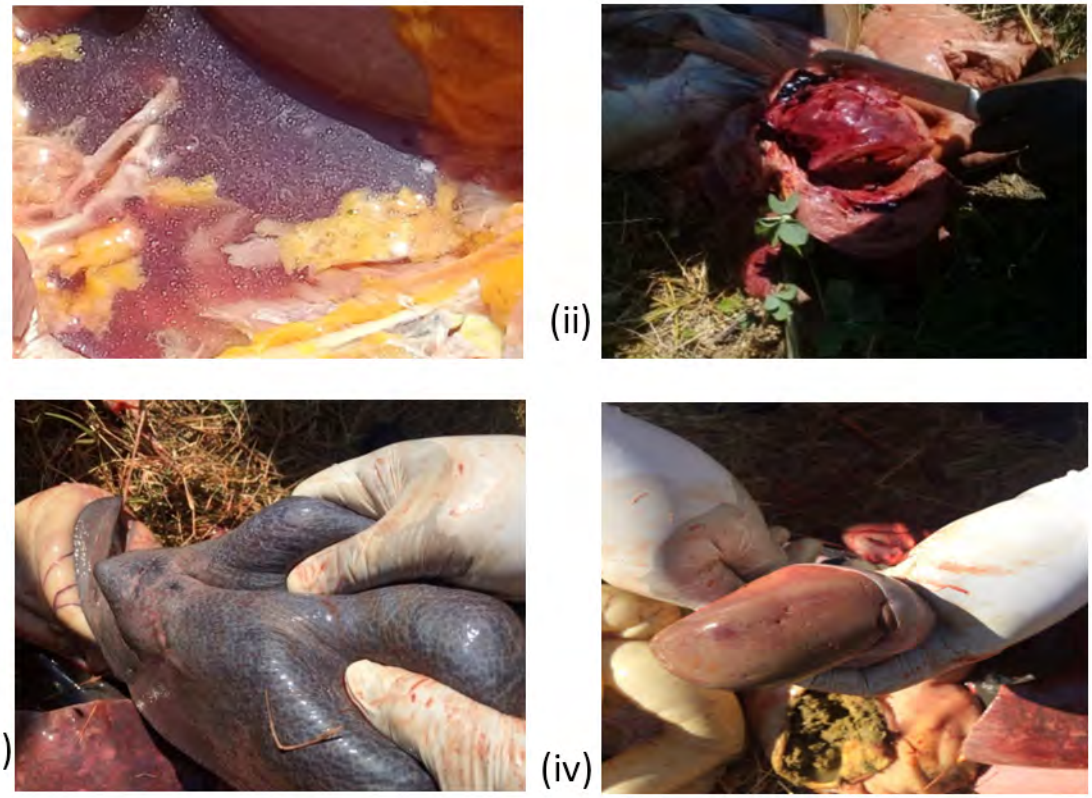
External examination

The external body surface had massive infestation of diversity of tick species both immature and adult ticks (Plate8).

Plate 8. High tick infestation on axilla, ears, neck, legs, perineal region and head

Examination of the internal organs

The muscles after skinning appeared pale a sign of anaemia suggesting a long-standing illness of the animal. There was excessive fluid in the chest cavity (hydrothorax) and heart sac (hydro-cardiac), there was severe lung edema, the spleen was enlarged with some hemorrhages, there were some hemorrhages in the heart and kidneys and had generalized fat degeneration (Plate9 i-iv).



(i) (ii) (iii) (iv)

Plate 9. Plate 9i Fluid filled chest cavity (hydrothorax), lung edema and fat degeneration; Plate 9ii-Internal surface of the heart (endocardium) showing hemorrhages; Plate 9iii-enlarged spleen; Plate 9iv-Hemorrhages in kidney.

Significant pathological findings

Several internal organs were collected including liver, lungs, spleen, kidney and lymph nodes, and were all preserved in 10% buffered formalin for histopathological examination. Pathological examination revealed that there was severe lung edema, excessive fluid in chest cavity and heart sac, generalized fat degeneration and hemorrhages in lungs, kidney, spleen and heart, unusual high tick infestation. Several internal organs were collected including liver, lungs, spleen, kidney and lymph nodes, and were all preserved in 10% buffered formalin for histopathological examination.

Cause of zebra mortality

Massive ecto-parasites caused stress to the animals, which may have compromised the immunity leading to latent viral infections, which are endemic in plain zebra to develop clinical symptoms ending up into Acute respiratory disease. In Tanzania plain zebra are known to harbor a number of viruses including Equine Herpes viruses (EHV1,4,9), Equine Arteritis virus (EAV) and African Horse

Sickness virus (AHS). For instance 17% of Serengeti plain zebra are exposed to EHV 1, 2% are exposed to EHV 4, 60% are exposed to EHV 9 and 24% are exposed to EAV (Fyumagwa & Wiik, 2003; Hoare & Fyumagwa, 2004; Borchers *et al*., 2008).

Impala mortality

Physical examination

The dead impala were thin and emaciated with heavy tick infestation, which is very unusual for such antelope species because are known to have strong inert resistance against ecto-parasites if are in healthy environment. Heavy tick infestation on skin was observed on two dead impala a female and a male (Plate 10).

Plate10. Two dead impala with evidence of heavy tick infestation

Clinical examination of impala

Many of the impala on the rangelands looked emaciated with ticks infestation observed from a distance. Several impalas were exhibiting diarrheic symptoms as seen on Plate11.

Plate 11. Thin looking impala on bear ground and watery stool (fresh& dried)

Laboratory examination of faecal samples

Laboratory fecal examination by floatation to determine the worm load revealed that the egg count per gram (EPG) for impala with diarrhea was over 4,350 and for those with normal droppings the epg was about 1000. The predominant worm species was Strongyles (Plate12). For small antelopes like impala such worm load was extremely high even for those with normal droppings.

Plate 12. Watery diarrhea from impala (left) and Strongyle eggs on one field under light microscope (right)

DISCUSSION

General observation

TANAPA has made an incredible improvement in the two protected areas that attract many visitors both local and foreigners for game viewing and camping. However, management of wildlife in small areas has some challenges because animals are not free to perform their natural behavior depending on the resource availability some of which are recognized by instinct of the animals. Such natural barriers can subject animals to stress and succumb to unexpected health problems and infectious diseases even to those, which the animals have innate resistance when in free ranging conditions.

Herbivores at Rubondo Island National Park

The investigation on disease problems in bushbuck and sitatunga at Rubondo Island National Park (RINP) has revealed that multiple factors are contributing to frequent antelope mortalities. Presence of two antelope species in the ecosystem is affecting the ability to modify the landscape, which is suitable for such small antelopes. Lack of coarse feeder herbivores like zebra is contributing to have a habitat which favours ecto-parasites multiplication in the grassland and hence infestation on antelope species. These ecto-parasites including diversity of tick species (Amblyomma variegatum and Rhipicephalus appendiculatus; Rh. praetaxtatus) and biting lice (*Damalinia sp.,*) are causing stress from bites and itching. Concurrently, the diversity of tick species present at RINP are known to transmit many blood parasites including Theileria species (Fyumagwa et al., 2013; Kilewo *et al*., 2018), and Eperthrozoonspecies (Mlengeya *et al.*, 2008), which have been detected in bushbuck and sitatunga. Similarly, Trypanosoma sp., which are transmitted by tsetse flies were detected in blood of these antelopes, an observation which is very unusual for health free ranging antelopes. Under normal circumstances these blood parasites should not cause any health problems in free ranging herbivores. The bushbuck that was found dead at the Kageye airstrip was confirmed at TVLA to have died of Severe Bronchopneumonia, which was caused by bacterial infection.

Herbivores at Saanane Island National Park

The SINP rangeland patches currently has two zebra, three wildebeest and 94 impala, which is equivalent to 18 Large Herbivore Units (LHU; 1 LHU = 250 kg animal). Under savanna rangelands, one LHU requires 4ha of grass per year; therefore, 18 LHU at SINP requires 72ha. From simple arithmetic it has been established that the SINP can accommodate only 18 LHU, assuming that even the rocky areas are used for grazing. However, in reality the grassland patches are smaller than the rocky areas; therefore, the capacity of the terrestrial environment to accommodate herbivores is far less than the arbitrary estimation of 18 LHU. This observation suggests that the grassland is not enough for the current herbivore biomass requiring supplementation especially during the dry season.

Generalized emaciation of herbivores on the island and symptoms of diarrhea to a number of impala, which is corresponding with high worm load, is a sign that affected animals are stressed from internal parasites, which suck blood and vital nutrients. Affected animals are therefore anaemic from blood loss caused by both gastro-intestinal parasites and ecto-parasites. Under free ranging condition on large protected areas, herbivores normally have wide home ranges, which help to reduce encounter rate with infective larvae of internal parasites and questing immature ticks (Kilewo *et al*., 2018, unpublished). Similarly, under free ranging herbivores do have places for grooming to reduce attaching ecto-parasites. However, in a small protected area like SINP, it is difficult for the herbivores to practice their natural behavior to evade infestation from parasites.

Nutritional stress in impala and other herbivores emanates from threefold, one is insufficient forage on rangeland, therefore, herbivores are starving, second the forage quality is poor therefore, little essential elements are available to herbivores and thirdly, high parasites are also reducing nutrients in the body of individual animals through sucking blood and essential elements.

Presence of clinical symptoms with high blood parasites, internal and ecto-parasites with noticeable mortalities suggests that there is an imbalance in host-parasite relationship and the small ecosystems are experiencing a "sick habitat syndrome" requiring some biological intervention.

CONCLUSION

RINP has good habitat which can support high diversity of ungulate species. However, despite presence of few ungulates in the area, ticks and lice infestation is very high on Sitatunga and Bushbuck because the antelopes congregate on small patches of short grassland. Therefore, cutting the dominant tall grass like Panicum maximum could help antelopes to distribute on wider rangelands and also reduce the humidity in the grassland which is unfavorable for ectoparasites. The RINP habitat is dominated by tropical forest with closed canopy; therefore, the survey work was conducted along the established road network and on few glades. Therefore, during the survey it was assumed that many of the antelopes congregate in open grassland and along the road side verges. The survey however, did not extend to Kasenye in the north of RINP because of physical barrier of fallen trees along the road at Kamea area. At SINP, nutritional stress in herbivores emanates from threefold, one is insufficient forage on rangeland, therefore, herbivores are starving, second the forage quality is poor therefore, little essential elements are available to herbivores (Masenga, E.H., 2018, unpublished), and thirdly, high parasites compromise body immunity and condition of individual animals by causing blood loss and anaemia, and deficiency of essential elements.

RECOMMENDATIONS

Following generalized poor body condition of the isolated meta-populations in two protected areas, it is recommended that;

- Helmeted guinea fowl are known to feed on ticks; therefore, introduction to these PAs should be a prerequisite.

- RINP has tall grass, which favors tick load, therefore, Zebra, waterbuck, reedbuck and wildebeest introduction is highly recommended to modify the landscape and act as dead end hosts for the parasites.
- Herbivores with poor or fair body conditions should be treated using long acting antibiotics (OTC 20%) and anti-theilerial drugs concurrent with deworming.
- Devise a system for automated application of insecticides to reduce tick and lice load.
- Food supplementation at SINP is recommended in dry season.

ACKNOWLEDGEMENTS

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IMPACTS OF CLIMATE VARIABILITY AND LAND USE LAND COVER CHANGE ON STREAM FLOW IN THE LITTLE RUAHA RIVER CATCHMENT, TANZANIA

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ABSTRACT
Little Ruaha River Catchment is the tributary of the Great Ruaha River which joins Great Ruaha River just after Ruaha National Park. The catchment area is characterized by multiple land use such as irrigated agriculture, livestock keeping, wildlife and tourism. Increased anthropogenic activities have had negative impacts on the Catchment in particular and other catchment resources. A study was conducted to investigate the hydrological impacts of land use land-cover changes and climate variability on stream flow of the Little Ruaha River. Remote Sensing (RS) and Geographic Information System (GIS) techniques and Soil and Water Assessment Tool (SWAT) model were used. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) images of 1990, 1998 and 2011 were used to locate and quantify the changes which have occurred in the catchment. The study revealed a significant change in land use land cover over the past two decades. Between 1990 and 1998, the woodland and wetland cover declined by 2.6% and 9% per year, and 1998 and 2011 declined by 1.4%and 3.1% per year respectively. Settlements and cultivation increased by 5.2% and 1.3% between 1990 and 1998. SWAT model was calibrated for the period of 2000 to 2006 based on the availability of climatic data and was validated for the periods 2007 to 2009. The Nash-Sutcliffe model efficiency (ENS) and coefficient of determination (R2) for annual flow were 58% and 65% respectively during calibration period and 72.68% and 77.35% during validation period respectively. Both land use land cover change and climate variability decreased runoff by 23% and 59.67% respectively. The climate variability influenced the surface hydrology more significantly than land use land cover change in Little Ruaha River catchment. The study concludes that, the modification of the land use and cover and climate variability has resulted in changes in temporal distribution of runoff. The study highlights the importance of catchment planning and management.

Keywords: Climate variability, Land use lands cover change Little Ruaha catchment, stream flow, Tanzania.

INTRODUCTION

Understanding the influence of land-use and land-cover change on river flow regimes is important for sustainable catchment management JJ Kashaigili (2006). Human activities in many parts of the world have greatly changed the natural land cover JJ Kashaigili (2008). Large tracts of natural vegetation cover have been converted into croplands or deserts, and natural wetlands have been drained and filled in order to feed and shelter expanding population. Worldwide it has become evident that river ecosystems have changed as a result of river regulation modifying the flow regime JJ Kashaigili and Majaliwa (2013). Also, the increased competition for water and alterations in land use in the upstream of many rivers, are argued to have contributed to change in hydrological regimes of many rivers and wetlands.

Against this background, this paper presents a study undertaken to investigate the impact of land-use and land-cover changes and climate variability on the stream flows of the Little Ruaha River Catchment (LRRC) in Tanzania. According to Mbungu and Kashaigili (2017), the Little Ruaha River Catchment is a sub catchment of Great Ruaha River catchment within Rufiji Basin. In terms of the national economy it is one of the country's most significant water ways, and contributes in hydropower production in Mtera dam. Furthermore, it is the main source of water during the dry season, and so is vital for the Iringa Urban domestic use and for Irrigation in many parts along the catchment. The land use planning for sustainable future requires investigations into possible land use changes and the impact it has on ecological functions and processes at the local level.

Use of Distributed Watershed Models

Hydrological processes and water resource issues are commonly investigated using distributed watershed model. These watershed models require physiographic information such as the configurations of channel networks, the location of drainage patterns, channel length and slope as well as sub basin geometric properties. Traditionally this information is obtained from maps or surveys. Over the last two decades this information has been increasingly derived directly from digital representations of the topography.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Little Ruaha River Catchment which runs from Saohill forests to Mtera Dam within Iringa region(Theodory (2014). Little Ruaha River Catchment is the tributary of the Great Ruaha River which joins Great Ruaha River just after Ruaha National Park (J. J. Kashaigili *et al.*, 2003). The Little Ruaha River has a very large catchment area, extending to some 5 500 square kilometers. Little Ruaha catchment serves many uses, including irrigation, livestock, and domestic uses to neighboring villages, fisheries and the aquatic flora and fauna. The Catchment area is located in the Southern Highlands of central Tanzania, within the Iringa Region and it lies between latitudes7° 12' 0"to 8° 36' 0" south of equator and longitudes 34° 54' 0" to 35° 54' 0" east of Greenwich.

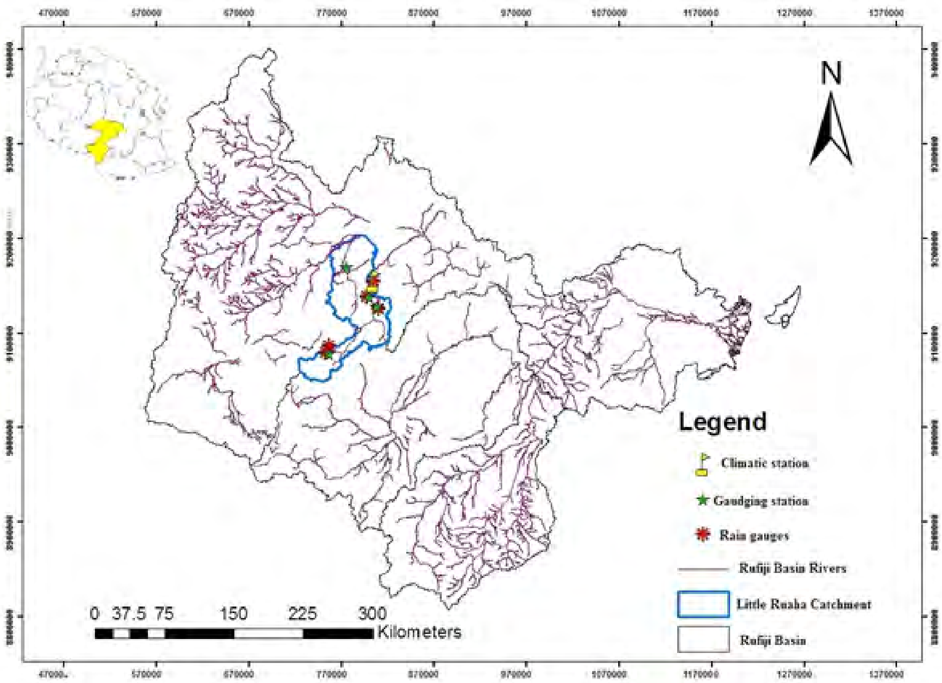

Fig. 1. Map of study area

MATERIALS AND METHODS

This study was carried out in four steps. First, a database was established and land use land cover maps for the years 1990, 1998 and 2011 were produced to analyse the land use land cover dynamics ERDAS (1999). Second, a SWAT simulation run was carried out using a set of input variables, and a sensitivity analysis was performed to identify parameters that influence the predicted stream flow the most. Third, the efficiency of the model was assessed by comparing simulated and observed annual and monthly stream flow. Fourth, in order to test the assumption that land use land cover change and climate variability has affected the watershed stream flow; further simulations were performed in different land use and climate scenarios.

SWAT input data and their sources

The basic data sets are: topography (DEM), soil, land use and climatic data. To capture the heterogeneity in physical properties, the watershed was subdivided into 29 (twenty-nine) sub-watersheds/basin, and each one of the sub-watersheds was partitioned into Hydrologic Response Units (HRUs) that consist of homogeneous land use, management, and soil characteristics. Simultaneously, spatial databases were developed using satellite images. The images available were TM and ETM+ datasets for 1990's, 1998's and 2011's. The satellite images were downloaded from the USGS website. Three land use land cover maps from 1990, 1998 and 2011 were produced using the ERDAS imagine 2011 software. Visual interpretation and supervised classification based on the maximum likelihood methods for the satellite images were employed. A representation of the regions of interest known as the training sites were digitized giving them different IDs and unique colours.

Other datasets used were:

Soil map and data: The soil data as required by SWAT to predict the stream flow should include the relevant hydraulic conductivity properties: the soil bulk density, the saturated hydraulic conductivity and the soil available water capacity (SOL_AWC. The soil data was obtained from the Tanzania soil map of 2001.

Stream flow data: Stream flow data was available for four Station sat 1KA32A, 1KA31, IKA21A and 1KA2A ranging in time from 1980 to 2012, though they had missing data, the missing data were filled by weather generator engine of SWAT model during simulation process.

Weather and temperature data

Weather data were obtained from four weather stations at Iringa maji, Iringa Met, Mafinga bomani and Mafinga National Service and ranges from 1980 to 2012 and minimum and maximu temperature data were obtained from Iringa Airport at Nduli area from 1980 to 2012

SWAT Model setup and Simulation options

Watershed delineations

The DEM was used to delineate the topographic characterization of the watershed and to determine the hydrological parameters of the watershed such as the slope, flow accumulation, flow direction, and stream network. Arc SWAT 2009, an ArcGIS interface, was used to delineate the watershed. To capture the heterogeneity in physical properties, the watershed was subdivided into 29 (twenty-nine) sub-watersheds or sub basins.

Hydraulic Response Unit (HRUs) Definitions

Before defining the HRUs the Landuse data were reclassified to match with the SWAT land use classification (Table 1). SWAT requires land use and soil data to determine the area and the hydrologic parameters of each land-soil categories simulated within each sub watershed. Therefore, land use slope and soil maps were overlaid. This study uses a dominant of land use and soil definition to create the Hydrologic Response Unit (HRU) for each sub basin. The abstraction data used was distributed as per sub basin and entered into SWAT interface independently for reach/river and ground water/boreholes each one of the sub-watersheds was partitioned into Hydrologic Response Units (HRUs) that consist of homogeneous land use, management, and soil characteristics whereby watershed was divided into 753 HRUs.

Table 1: Little Ruaha Land use classes matched with the SWAT land use classes

USGS LU Class	SWAT LU Class	LU Class	% total catchment area (ha)
Residential	URBN	Built-up area	15778.47
Wetlands-Non-Forested	WETN	Wetland	40868.84
Range-Brush	RNGB	Bush lands	88949.07
Range-Grasses	RNGE	Woodland	177202.58
Agricultural Land-Generic	AGRL	Cultivated land	172870.22
Wetlands-Forested	WETF	Riverine forest	13391.96
Agricultural Land-Close-grown	AGRC	Cultivated woodland	18521.84
Pasture	PAST	Grassland	41814.98
Forest-Mixed	FRST	Natural forest	19255.42
Water	WATR	Water	5483.28
Forest-Evergreen	FRSE	Plantations	18981.52

Simulation and Sensitivity analysis

Simulation of the stream flow

The hydrological processes simulated by sub basins as included in the water balance equation are precipitation, surface runoff, evapotranspiration, percolation and return flow. The daily weather data required by SWAT are precipitation, temperature (maximum and minimum), solar radiation, relative humidity and wind speed. After inputting precipitation and temperature data, weather generator then generates solar radiation and relative humidity for the day. Finally, wind speed is generated independently. Runoff is simulated separately for each of the HRU and combined to give the total stream flow for the other sub basin which is then combined with stream flow for the whole basin. Through delineating sub-watershed and creating Hydrological Response Unit (HRU), the SWAT model simulated the water balance of the catchment. According to Inca (2017)SWAT predicts the surface runoff using the modified SCS Curve number method. In this study the SCS Curve Number which is a function of the soil permeability, land use and antecedent moisture condition was used for simulation of infiltration and potential evapotranspiration.

Sensitivity analysis

Quantifying model sensitivity to parameter changes is an important step in understanding model performance, and a crucial undertaking prior to model calibration; therefore, addressing whether the appropriate quantity and quality of data can be obtained to provide realistic model outputs given parameter sensitivity (Baker and Miller (2013); Tracy (2010). Sensitivity analysis was done prior to auto calibration and model validation in order to identify parameters which influence model the most. Different lengths of observed data records have been used in this study to assess the influence of data adequacy in parameters identification. van Griensven *et al*. (2006) characterize Global rank 1 as "very important”, rank 2 to 6 as ‘important”, rank 7 to 19 as “slightly important” and rank 28 as “not important. Initially, four SWAT parameters were chosen to test surface runoff response sensitivity that include: curve number (CN), percent land cover, saturated hydraulic conductivity (Ks), and soil hydrologic value (HV). Latin Hypercube sampling based on one factor at a time (LH-OAT) which is incorporated in AVSWAT as an extension was used to identify parameters that have a significant influence on model simulations (Fish & Road, 2010).

Model calibration and validation

Calibration is tuning model parameters based on checking results against observations to ensure the same response over time. This involves comparing model results, generated with the use of historic meteorological data, to recorded stream flows. In this study coefficient of determination (R2) and Nash-Sutcliffe model efficiency (ENS) values were checked to see the model performance. New SWAT project was built from the land use land cover map and database files of climatic data for Little Ruaha River Catchment was used for model calibration. Annual runoff of 2000-2006 and land use land cover map of 1990 was used for model calibration, and annual runoff of 2007-2009 and land use land cover map of 2011 was used for model validation. Nash–Sutcliffe model efficiency (ENS) and the coefficient of determination (R2) were used to assess the predictive power of the SWAT model.

SWAT model scenario analysis

The SWAT model was used for scenario analysis under climate variation and land use land cover change by running the calibrated SWAT model for each of the four combinations of two time-periods and two land use land cove maps. The land use land cover map of 1990 and climate variation of 2000–2006 was used to quantify the effects of land use land cover change and climate variations on stream flow characteristics. The influences of the land use land cover and variations in climate (temperature and rainfall) were quantified on monthly and annual time step by comparing SWAT outputs to baseline run (the swat run using base map). To evaluate the effect of land use land cover change and climate variability on hydrology, the approach of one factor at a time was used (i.e., changing one factor at a time while holding others constant). Meteorological data of the two-time epochs of 1981–1990 and 1991– 1999 were selected, and each time epoch included one land use land cover map. The land use maps of 1998 and 2011 were used to represent the land use land cover patterns of 1990s and 2000s for the two-time epochs respectively. The calibrated SWAT model was run for each of the four combinations of two-time epochs and two land use land cover maps (called four scenarios hereafter). The influences of the land use land cover change and climate variability were quantified by comparing the SWAT outputs of the four scenarios as follows: S1: 1998 land use land cover and 1981–1990 climate data.S2: 2011 land use land cover and 1981–1990 climate data.S3: 1998 land use land cover and 1991–1999 climate data.S4: 2011 land use land cover and 1991–1999 climate data The contrast between S1 and S2 indicated the influence of land use land cover change between the two periods. The contrast between S1 and S3 indicated the influence of climate variability on stream flow characteristics and S1 and S4 indicated the combined effects of land use land cover change and climate variability on stream flow.

Table 2:Net area change between 1990 and 1998, and 1998 and 2011 and percentage annual rate of change

Land Cover class	Net area change				Annual rate of change			
	1990 -1998		1998 -2011		1990 -1998		1998 -2011	
	Area(ha)	%	Area(ha)	%	Area(ha/year)	%	Area(ha/year)	%
Built up area	+11703	+1.8	+12808.4	+2.0	+1462.875	+5.2	+985.3	+2.4
Natural forest	-13871.6	- 2.2	+1387.18	+0.2	-1733.95	- 26.3	+106.7	+1.3
Wetland	-17868.3	- 2.8	-7155.7	- 1.1	-2233.54	- 9.0	- 550.4	- 3.1
Woodland	-15872.4	- 2.5	-13011.5	- 2.1	-1984.05	- 2.6	- 1,000.9	- 1.6
Grassland	-52195	- 8.2	-20123	- 3.2	-6524.38	- 5.0	- 1,547.9	- 1.4
Cultivated land	+19943	+3.1	+3691	+0.5	+2492.875	+1.3	+283.9	+0.1
Riverine forest	-12594.5	- 2.0	+8916.1	+1.4	-1574.31	- 58.2	+685.9	+5.9
Cultivated woodland	+6844.7	+1.1	+46190.6	+7.2	+855.5875	+3.2	+3,553.1	+4.9
Bush land	+23975.9	+3.8	-3820	- 0.6	+2996.988	+4.2	- 293.8	- 0.4
Water	+678.2	+0.1	-1807.16	- 0.3	+84.775	+1.4	- 139.0	- 3.3
Plantations	+49022.7	+7.7	-26228.7	- 4.1	+6127.838	+9.0	- 2,017.6	- 4.8

DISCUSSION

From the study and data obtained from satellite imagery, Little Ruaha River catchment has undergone changes in land use and land cover over the past two decades.

Woodlands decreased by- 2.5 % between 1990 and 1998 and -2.1% between 1998 and 2011 (Table 2). This decrease might be due to clear felling of trees for expansion of agricultural farms also for charcoal making as a fuel wood. Built up area increased in periods of 1990 -1998 and 1998 -2011 by+ 1.8 % and 2.0%, the reason of this might be due to rapid expansion of town centers like Iringa, Kilolo and Mafinga. The growth of these centers might be attributed by rural urban migration. Natural forest is another land cover which experienced notable changes between two periods. The results show that, natural forest cover decreased by - 2.2 % between 1990 and 1998, this might be due to encroachment of people for timber and firewood. Between 1998 and 2011, natural forest cover increased by and 0.2%, wetland decreased by - 2.8 % in year 1990 to 1998 and continued to decrease by -1.1% in year 1998 to 2011.The decrease in wetlands might be due to drying up as a result of decreasing in rainfall as revealed by trend analysis. Grassland decreased by - 8.2 % between 1990 and 1998 and continued to decrease by -3.2% in the year 1998 to 2011. Riverine forest decreased by -2.0 % between 1990 and increased by+1.4% between 1998 and 2011.Bush land increased by + 3.8 % between 1990 and 1998 and decreased by -0.6% between 1998 and 2011. Water increased by +0.1 % between 1990 and 1998 and decreased by -0.3% between 1998 and 2011.Plantations increased by + 6.0 % between 1990 and 1998 and decreased by -2.4% between 1998 and 2011, the fluctuation in plantations this might be due harvesting and 2011, the fluctuation in plantations this might be due harvesting and planting new trees and expansion of tree plantations. Cultivated land increased by + 3.1%between 1990 and 1998 and continued to increase by +0.52% between 1998 and 2011.

Sensitivity analysis

In this study 'CN2" was identified as very important parameters, GWQMN, ALPHA-BF, ESCO, SOL-AWC and SOL-Z as important parameters which retain a rank between 2 and 6. Parameters like, CH_N, Ch- K2", "SLSURBBSN"," GWQMN" and "CANMAX', etc were identified as slightly important parameters and the rest parameters do not influence model output. This suggests that sensitivity analysis tool built in SWAT model is robust and can be applied in ungagged catchment for identifying hydrological controlling factors.

Auto calibration and model validation

All-important parameters with mean sensitivity index greater than zero, were considered for optimization. In this study Alpha_Bf, Cn2, Epco, Sol_z, Gwqmn, Ch_n2, Esco, Sol_Awc and Surlag parameters were optimized for model calibration. The Nash and Sutcliffe (R2) and coefficient of determination for calibration period were considered satisfactory since the model was capable of producing about 58% and 65%respectively of the variance on daily observed record

The long-time annual flows between observed and simulated were comparable with a mean of14.28m3/s and 15.68m3/s respectively. After model calibration followed by model validation where by Nash R2 and coefficient of determination registered 72.68% and 77.35% respectively. Model performance with respect to monthly flow predictions during the calibration and validation period (i.e.R2= 65 and 77.35%) is comparable to Birhanu (2005)calibration results (i.e. R2=75.9%), Ndomba et al. (2005)(R2 =65%). In comparison to the results of this study, it clearly indicates that optimal parameters as derived from Auto calibration procedure and 7 years of data from the model performance were assessed and found to be appropriate and can be used to simulate stream flow in Little Ruaha Catchment. According to modelling experience by Water Resources Engineering Project based at University of Dar es salaam Ndomba et al. (2005), percentage missing of data greater than 15% is not recommended for modelling and this has not affected this study since data from all stations used for simulations has percentage of missing data less than 15%. The model evaluation shows good agreement between the observed and simulated stream flow although model over estimate flow especially in 2002. Through close examination of the data revealed that rainfall records in some stations were low and observed flow was high especially during rainy season. The modelling suggests that using processed or adequate and reliable spatial rainfall data, long period of calibration flow data, settling up a fully distributed watershed i.e. increasing number of sub basins and more rainfall stations records model could improve the results of this study.

Hydrological impacts of climate variability and land use land cover change. The contrast between S1 and S2 (Table 4) indicated the influence of land use land cover change between the two periods. The land use land cover change decreased runoff by 1.87 mm which accounted for 23%. The contrast between S1 and S3 indicated the influence of climate variation. The climate variation decreased runoff by 4.85mm, which accounted for 59.67% of the total runoff reduction. The contrast between S1 and S4 indicates the combined effect of land use land cover change and climate variability which accounted 8.13mm reduction in runoff. The above results showed that, the land use land cover change and climate variability during 1990s and 2000s both decreased runoffs, but the contribution of climate variability was far greater than that of land use land cover change. It should be pointed out that, simulation of measured runoff reduction caused by both climate variability and land use land cover change (6.72 mm) was slightly smaller than simulated combined effect. This result can be compared with which obtained that the effect due to land use land cover change accounted for 9.6% and effect due to climate variation was 95.5%. Also a study by Githui and Mutua (2007), in Nzoia River basin, Kenya revealed that without climate variability, land use land cover changes would account for difference in runoff of about 55-68%. On the other hand, change in climate without land cover change accounted for a difference in runoff of about 30-41%.

CONCLUSION

This study investigated the impacts of land use land cover changes and climate variability in the Little Ruaha River catchment. This was an integrated assessment which used combined GIS and remote sensing methodological approaches as well as physical based hydrological model (SWAT) in understanding the land resources change and climate variations and their resulting effects on stream flow characteristics. The findings revealed that the study area has undergone notable changes in terms of land use land cover for the period 1990, 1998 and 2011. The woodland areas were found to be highly impacted, notably by the increased anthropogenic activities. The settlement and cultivated land were found to have consistently increased between the two periods under investigation as well as the cultivated woodland. Results from hydrological modelling revealed that, both land use land cover changes and climate variations have reduced the stream flow by 23% and 59.67%respectively. There have been significant changes in land use land cover in the catchment as well as hydrological characteristics of the catchment. The results revealed the fact that the amount of flows generated from the high catchment has statistically changed over the time. SWAT proved to be a useful tool for assessing the effects of environmental changes including land use land cover changes and climate variability in the Little Ruaha catchment. The Nash-Sutcliffe model efficiency and coefficient of determination (R2) were 58% and 65% as well as 72.68% and 77.35% for calibration and validation periods respectively; indicating SWAT performance in Little Ruaha catchment was very good. The study highlights the importance of integrating remote sensing techniques and hydrological modelling in understanding the catchment resources dynamics and generating information that could be used to overcome the catchment problems for the sustainability of the catchment resources

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COMPLIANCE OF MINING COMPANIES ON REGULATORY FRAMEWORK IN TANZANIA: EVIDENCE FROM COMMUNITY PERSPECTIVES IN KAHAMA DISTRICT

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ABSTRACT

The mining sector for most developing countries including Tanzania has become an important sector for the economy. However, the sector still faces many challenges it must overcome to reach its full development potential. This paper assessed whether mining companies complied with the regulatory framework of the mining sector based on community perspectives in Kahama district. Both cross-sectional and case study designs were used for the study. A total of 215 households were sampled for the study based on Bailey's proportionate formula computed at 9.3%. The respondents were selected using simple random sampling technique. Data were collected using a questionnaire, focus group discussions, observations and documentary reviews. While content analysis was used to analyse qualitative data, factor analysis was employed to handle quantitative data. The Cronbach's α obtained was 0.760 for perceived compliance, indicating that the mining companies complied with some of the items as per Cronbach's scale (α = 0.70), such as consultation for views on issues, publication of anticipated effects and benefits through posters in strategic public areas and meetings with communities. However, it was also evident that the mining companys' operations affected to a large extent the qualities of water, soil, air, use of available resources within operation areas. The results showed further that the company was also not complying with better practice on issues like noise reduction due to vibrations, purchase of items locally produced, and employment of indigenous manpower. This suggests that although large mining companies are useful for Tanzania, discouraging challenges that existed, especially with respect to the distribution of benefits among its citizens, investors and the country at large needs to be addressed collectively with the involvement of key players if we are to sustainably benefits from the extractive sector.

Keywords: local communities;mining policy; mining companies; mining sector regulatory framework

INTRODUCTION

The mining sector has become an important sector for most developing countries for their economy. In view of this, most of the developing regions of Latin America, Asia and Africa are abundantly endowed with mineral resources that are essential for modern production and consumption worldwide (Besada et al., 2015). Africa, for example, hosts over two-thirds of the world's reserves of platinum which is essential in the electronic industry; Latin America accounts for over half of the global production of copper; and Asia accounts for over half of the world's coal and more than a third of global iron-ore deposits used for energy and steel production (Besada et al., 2015). Africa also accounts for about 12% of the world's oil reserves, 40% of its gold, 80% to 90% of the chromium and platinum group of metals, 85% of phosphate reserves, more than half of cobalt and one-third of bauxite (UNECA & AU Commission, 2012; African Development Bank, 2013). The US Geological Survey estimates also show that Africa expanded its metal and minerals extraction by 78% between 2010 and 2017 (US Geological Survey, 2010). In this regard, richness in terms of natural resources, the mining and extractive sector constitutes a major share of exports and tax revenues for countries in the Global South and holds enormous potential to finance rapid economic development for poverty reduction.

Despite the expected advantages, harnessing these benefits remains problematic as many countries do not reap the full potential of their resources endowments. Rather than providing for broad-based and sustainable economic growth, resource revenues often end up benefiting only a small segment of local elites and foreign investors partly due lack of compliance and/or weaknesses in the legal frameworks. While a number of studies such as by Kabote & Niboye, 2013; Poncian, 2015; Kahyarara, 2015; Lange & Kinyondo, 2016; Maliganya & Renatus, 2017 have been carried out in relation to the general contribution of the sector to the economy, studies on the compliance of mining companies in the context of the legal framework based on the perspectives of local communities remain limited.

Although empirical evidence is increasingly confirming that the legal and regulatory frameworks for resource extraction in the Global South are often designed to maximize benefits in the form of employment, local investment or monetary compensation to local population, the return from such resources have not usually matched with the expectations (Lange, 2006; Tsui, 2011; Ross, 2012). Consequently, concerns have been increasingly being raised that wealth from extractive resources has not fairly been sufficiently transformative in African countries, and there has been little progress in overall development and welfare in these countries (Global Witness, 2010; Africa Progress Panel, 2013).

While the reasons for the prevalence of this situation are many and varied, literature suggests that the situation has greatly been attributed to the unsatisfactory state of affairs due to non-compliance of foreign investors with the national regulations coupled with weak governance in the host countries, including Tanzania. Consequently, the failure to manage national resources properly has given rise to the troubling questions on how the continent can be so rich in natural resources, yet so poor in terms of human development (Adjei, 2007; Noras, 2016; Simon, 2016).

Despite the high growth rates recorded in some countries such as Botswana in recent years, many countries including Tanzania in the region have failed to turn resource wealth into inclusive economic development. If anything, resource wealth has in many cases resulted in increased income inequality and even triggered social and political instability as the cases in the Democratic Republic of Congo, Sierra Leone, and South Sudan, a situation described as the resource curse (Collier, 2010; Lange, 2011). However, evidence is suggesting that enhanced practices of good governance has been associated with the experience of a few resource endowed countries in Africa such as Botswana, Namibia, Ghana and Mozambique. These countries have been using their resource-wealth to stimulate high growth, create strong private sector with additional jobs and transform their development path towards achieving sustainable development (Kaufmann, 2012; Griddle, 2004).

In Tanzania, despite a remarkable history of its mineral endowments, the country has not succeeded in translating its mineral wealth into overall economic development. Factors such as lack of transparency and accountability in the sector have allowed for the vast imbalances between the wealth created through resource exploitation and poor human and economic development especially among the local population (Lugoe, 2012; Kahyarara, 2015). For example, lack of transparency and accountability applies to the negotiation of contracts and on the various payments and royalties made by multinational corporations to governments which have always not been fair deals to host countries (Maliganya & Bengesi, 2018).

In this regard, it has become clear that the need for an effectively monitored legal and regulatory framework is increasingly becoming important for the countries rich in natural resources. While some governments have recognized the potential role the mining sector could play towards economic growth and development, there have been numerous resource conflicts between communities, government and private companies (Lange, 2008; Lugoe, 2012; UNECA, 2012). More importantly, the recent new discoveries of natural resources such as natural gas and oil, along with the rise of local and global environmental, economic and human rights activism have led to increased demands for the government to respond to the needs of the public in Tanzania.

The predominance of public discontent against natural resource investors has been witnessed in different areas such as in Mtwara, Mara and Geita to mention a few. According to Lange (2011), the Tanzania population in general, not only those directly affected by mining operations, is extremely resentful of large scale mining. Conversely, the net impact of the mining sector on Tanzania's development has remained limited. Interestingly, this fact has been recognized by the government and is also manifested through increased public discontent towards the sector's unsatisfactory performance (Collier, 2007; Kabote & Niboye, 2013; Poncian, 2015; Kahyarara, 2015; Lange & Kinyondo, 2016; Maliganya & Renatus, 2017).

This raises a number of questions on whether large scale mining companies comply with the provisions stipulated in the legal framework. This situation if not well addressed, it may likely lead to far reaching implications not only on part of the country at large but also on communities especially those found in proximity to areas where such resources are being extracted including the resource curse. This paper examined the extent to which mining companies comply with the regulatory framework in Kahama District. The paper illustrates the challenges in the mining sector by assessing the response of mining companies to the regulatory framework of the mining sector in Tanzania. The paper is expected to come up with practical recommendations for policy options on how Tanzania can implement sound and well monitored regulations in the sector for the attainment of sustainable development outcomes. In light of this, the findings of this paper essentially shed light on the previous and current efforts towards sustainable exploitation of resources in the respective sectors for the realization of sustainable development goals as stipulated in the national legal documents.

This paper is guided by the Institutional Theory. This is a theory that predicts processes by which social and political structures including rules, norms and routines become established as an authoritative guideline for behaviour that governs interactions in society. The theory asserts that authoritative guidelines for behaviour are created and adopted over time (Scott, 1995). This implies that for organizations including mining companies to survive and thrive, they must conform to the rules and belief systems prevailing in the environment. Kraft & Furlong (2017) contend that the institutional theory is a policy making mechanism that emphasizes that formal and legal aspects of government directives should be complied with.

Viewed in the context of this paper, this theory is ideal as most of what is happening in the mining sector in any country of the world is regulated, surviving and thriving under the rules, norms and values of a given country. Indeed, the policy framework of the mining sector in which these actors operate is defined by both national legal framework and corporate practices which establish norms pertaining to accountability measures, revenue sharing, local employment and investment requirements as well as social and environmental safeguards. This study therefore aims to i) assess the response of large scale mining companies to the regulatory framework for enhanced local livelihoods in Kahama District and ii) explore the perceptions of communities living in and around mining areas to ascertain how mining companies comply with the regulatory framework of Tanzania.

MATERIALS AND METHODS

Research Design, Study Area and Sampling Procedures

The study on which this paper is based employed both cross-sectional and case study designs. While cross-sectional design was applied since data were collected at a single point in time, case study design was considered useful because the study involved looking at the social and environmental impacts of a mining company (Buzwagi Gold Mine) as a single case to study. In this case, the issue of generalization would be limited to the context of the study area (Bryman, 2008). The study was conducted in Kahama District in three (3) mining village communities namely Mwendakulima, Mwime and Chapulwa.

The study district, ward and villages were purposively selected based on their proximity to mining areas (Buzwagi) approximately 4 kilometers away. The unit of analysis was a household of local communities in Kahama District where the heads of household were involved in the survey for interviews. The district is one of the districts in Tanzania where both large and small mining activities have been widely carried out due to its rich gold deposits (URT, 2013). Although the district is one of the most extensively mined areas in Tanzania, yet it has remained with illusions of expected benefits from gold mining (Mwaikenda & Wambua, 2014). Out of the total population of 2300 households for the three village communities, 215 households were sampled for the study based on Bailey's proportionate formula computed at 9.3% (Bailey, 1994). The respondents within individual villages were selected using simple random sampling technique which gave each of the respondents equal chances of being represented in the survey (Table 1).

Table 1: Sample Size Distribution by Villages (n = 215)

Village	Number of households	Sampling percentage	Sampled households in village
Mwime	1404	9.3	131
Mwendakulima	686	9.3	64
Chapulwa	214	9.3	20
Total	**2,304**		**215**

Source: Field survey (2017).

Methods of Data Collection

Data for this paper were collected using various methods (Cresswell, 2009). Systematic review method of literature was used for policies and legislation from Tanzania and best practices elsewhere. Household survey and key informant interviews with technical personnel from government and mining company officials were also conducted to determine the extent at which communities understood issues of environmental sustainability and community engagement and social responsibility in areas where mining operations were undertaken. Focus group discussions (FGDs) were also conducted which focused on how the company and government engage with local communities and whether they demonstrated willingness and interest in implementing social inclusion policies in relation to mining operations in the area. In each study village, three FGDs were conducted composed of 6-10 people for effective discussions (Cresswell, 2014).

DATA ANALYIS

This paper adopted the exploratory factor analysis to explore the relationship amongst variables and reduce them into fewer factors that were easily managed. A reliability analysis was conducted based on a calculation of correlation among the statements using Cronbach's α (Chen & Popovich, 2002). A Cronbach's α of 0.7 or greater indicates that a scale is reliable. In this study, the Cronbach's α obtained was 0.760 for perceived compliance. On the other hand, the validity of the research instruments was assessed using Principal Component Analysis (PCA) to identify which statements were independent from one another. The data were rotated by using direct Oblimin, which was chosen because it assumes that the extracted factors are related. Also, the data were suppressed at 0.4 factors loading. Before proceeding with factor analysis, the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test were conducted to determine whether or not it was appropriate to conduct factor analysis.

RESULTS AND DISCUSSION

Sampling Adequacy and Reliability of Compliance Items

Factor analysis was used to explore the compliance score basing on pre-stated system of governance in the national legal and regulatory frameworks. Using an exploratory factor analysis (EFA), the Kaiser-Meyer-Olkin test resulted in a maximum value of 0.77 for communalities, indicating an adequate measure of sampling design employed in the study (Kaiser, 1970; Field, 2009; Bengesi, 2013). In addition, there was a significant correction of items in the measure of compliance subjected to communities (p-value <0.01), thus supporting the fit of test items into the analysis (Pallant, 2011).

Table 2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.771
Bartlett's Test of Sphericity	Approx. Chi-Square	2.237E3
	df	171
	Sig.	0.000

Source: Field survey (2017).

Selection of Compliance Variables

Suitability of Variables

The amount of variance explained by test items was initially used to determine the dominant variables subjected to a reduction process of factor analysis; those under 0.3 among the variance explained were suppressed (Pallant, 2007). Based on this procedure, all variables suited into the reductive analysis were explained within a range of 0.483 to 0.865 (Table 3).

Table 3: Communalities

Variables	**Initial**	**Extraction**
The mining company consulted for views on issues	1.000	.865
Publicity of anticipated effects and benefits before project	1.000	.847
Public meetings were held with the affected parties and communities to explain the effects before mining operations began	1.000	.817
Mining operations affect the quality of water in our area	1.000	.705
Mining operations affect the quality of air in our area	1.000	.734
Mining operations have induced noise and vibration pollution in our area	1.000	.633
Mining operations affect the quality of soil in our area	1.000	.723
Mining operations affect light in our area	1.000	.719
Mining operations interfere with radio waves	1.000	.583
The Mining company abides to the conservation of plants and animals in surrounding areas	1.000	.747
The mining company uses the available natural resources sustainably	1.000	.804
Mining activities have resulted in a release of modified organisms	1.000	.636
The mining company abides to the conditions to rehabilitate degraded land after operations	1.000	.788
The mining company abides to the restoration of the environment for affected living organisms (plants and animals) in and out operation areas	1.000	.801
Mining company offers relocation areas to people affected by mining project operations within the mining areas	1.000	.730
Mining company offers compensation to people affected by mining project operations within the mining areas	1.000	.734
The mining company procures goods and services available in your area	1.000	.483
Mining company offers employment to local people from the community	1.000	.529
Mining company keeps demarcated mining area to avoid conflict	1.000	.664

Extraction Method: Principal Component Analysis.
Source: Field survey (2017)

Factor extraction

Factors were extracted using the total variance explained by each factor among community respondents; under this, principal component was used in the analysis to obtain linear components with eigenvalues above 1.0 after extraction (Bengesi, 2013; Pallant, 2011). Out of the test items, the analysis extracted five major dominant components, which constituted a total variance of 71.3% explained with regard to compliance.

Oblique factor rotation

Since items were significantly correlated (X^2 = 2.237E3, p-value <0.01) therefore, oblique rotation was applied to optimize the structure of factors so that deviations in total variance among the factor components were minimized. As can be seen in the total variance that, before and after rotation the dominant factors rated 4.447, 3.705, 2.396, 1.786 1.207 and further optimized for 3.995, 3.190, 2.373, 3.229, 2.236 respectively (Table 4). Furthermore, the oblique rotation presented both pattern and matrix structure of factors as seen in Table 5 below.

Table 4: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.447	23.406	23.406	4.447	23.406	23.406	3.995
2	3.705	19.499	42.905	3.705	19.499	42.905	3.190
3	2.396	12.612	55.517	2.396	12.612	55.517	2.373
4	1.786	9.401	64.918	1.786	9.401	64.918	3.229
5	1.207	6.351	71.269	1.207	6.351	71.269	2.236
6	.848	4.461	75.730				
7	.779	4.100	79.830				
8	.589	3.098	82.927				
9	.507	2.667	85.595				
10	.472	2.486	88.081				
11	.412	2.170	90.251				
12	.325	1.709	91.959				
13	.299	1.574	93.533				
14	.263	1.383	94.916				
15	.247	1.298	96.214				
16	.214	1.126	97.340				
17	.203	1.071	98.411				
18	.169	.887	99.298				
19	.133	.702	100.000				

Extraction Method: Principal Component Analysis.
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance

Structure Matrix of Factor Analysis

Rotation of the analysis resulted into a similarity of pattern and structure matrices, indicating a direct correlation among compliance factors with regard to mining activities in the study area. This argues positively for the analysis undertaken for this study. In addition, a double loading in some of factors like noise and vibration, demarcation of the mining areas and release of modified organisms justified the use of oblique rotation in this study (Thompson, 2004; Matotola & Bengesi, 2019).

Table 5: Structure Matrix

Factors [a]	Component				
	1	2	3	4	5
Mining operations affect the quality of soil in our area	.830				
Mining operations affect light in our area	.829				
Mining operations affect the quality of air in our area	.815			.324	
Mining operations affect the quality of water in our area	.796				
Mining operations have induced noise and vibration pollution in our area	.750			.332	
Mining operations interfere with radio waves	.728				
Mining company offers compensation to people affected by mining project operations within the mining areas		.852			
Mining company offers relocation areas to people affected by mining project operations within the mining areas		.852			
Mining company keeps demarcated mining area to avoid conflict		.726		.454	
Mining company offers employment to local people from the community		.705			
The mining company procures goods and services available in your area		.554	.330		
The mining company abides to the restoration of the environment for affected living organisms (plants and animals) in and out operation areas			.884		
The mining company abides to the conditions to rehabilitate degraded land after operations			.883		
The mining company consulted for views on issues				.927	
Before the start of the project, the mining company publicized its anticipated effects and benefits by posting posters in strategic public areas				.918	
Public meetings were held with the affected parties and communities to explain the effects before mining operations began				.899	
The mining company uses the available natural resources sustainably					-.879
The mining company abides to the conservation of plants and animals in surrounding areas					-.859
Mining activities have resulted in a release of modified organisms			.595		-.651

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization

Linear Components of Compliance

Oblique rotation converged into 9 iterations which featured into 5 linear components that with regard to issues of compliance were termed as pollution control (Component 1), compensation and resettlement (Component 2), measures for mining closure (Component 3), social accountability (Component 4), sustainable environmental management system (Component 5).

Pollution Control

The regulatory framework governing the mining sector indicates that Section 4 (1) of the Environmental Management Act (EMA, 2004), provides for the right to clean, safe and healthy environment (URT, 2004; 2009; 2010). Section 7(1) provides for the principles of environmental management and enhancement, promotion, protection, conservation and management of the environment. Section106 (1) provides for pollution prevention and control.

Despite these elaborative provisions in the regulatory framework, the findings show that mining activities highly interfered with control of the environment in different ways (Table 5). The environment was generally polluted, mostly in light intensity, followed by low quality of the soil. The quality of water and air was also affected. Interference of radio waves as well as noise and vibration were also realized during mining operations. These findings suggest that, among the components of compliance, failure to undertake best practice, pollution control carried the highest explanatory power in the community (23.4%) when compared to the rest, indicating that pollution was the most reported case during mining operations.

Focus group discussions with community groups, key informant interviews and observations also showed that mining activities have far reaching environmental impacts that affected the livelihoods and health of communities due to pollution, especially on water. The effects were felt more in the adjacent communities and those residing some distances from the mine due to noise and air disturbances. Overall, the findings of this study indicate generally that, despite the indications that the mining company was complying on some aspects, community responses were largely not in agreement with this regarding the environmental problems that were most significant in relation to water, noise, air pollution, waste management and land degradation.

Bitala *et al*. (2009) pointed out that the contamination of water from River Tighite and Nyabigena and sediments soil and the environment in the vicinity of North Mara Gold Mine between Kwimanga and Kwinyinyi was due to the presence of chemical contents of the heavy metals and cynides leakeges from large scale operations. Consequently, this was considered beyond the maximum permissible concentrations as a pollution of environment. Likewise, the presence of gaseous materials such as Sulphur Dioxide, Carbon Monoxide, Carbon Dioxide whose concentrations were then compared to standards by WHO, Tanzania and US Environmental Protection Agency (EPA) were found to be higher for people's health and sustainability of the ecosystem in the respective areas. In view of this, it was an indication of non-compliance as a result of the on-going gold mining in the respective areas.

Maliganya & Renatus (2017) also came up with similar observations in a study conducted in Geita District in villages of Nyakabale and Nyamalembo in which the communities have dug open wells near the mining operations where most of the boreholes were downstream. In Zimbabwe, similar cases were observed at Shurugwi mine operations indicated contamination of river water and underground water reserves. The chemicals from the mine flow into Mutevekwi River that forms the source of water for domestic use to the community. According to the study, the situation has resulted in the death of livestock and chemical effects to fish and children. However, for all the livestock that died as a result of such poisonous water, the owners were not adequately compensated. In this situation, waste management was one of the key drivers of negative environmental effects of mining activities in the areas under study (Chaumba, 2017).

Compensation and Resettlement of Local Communities

One of the basic gains of mining operations in any area are the compensations and financial flows of revenue from the mining company that in essence is a catalyst for change and poverty reduction (Kumi, 2014). People who resettle to make way for large-scale infrastructure development are widely acknowledged as vulnerable to a range of impoverishment risks in the field of development-caused displacement and resettlement. Global policy safeguards and standards aim to protect affected populations by requiring project developers to avoid displacement where possible, mitigate and manage harm through resettlement (Keenan et al., 2016). However, depending on the country practice, mining contracts may contain basic obligations that companies must comply with relating to issues such as resettlement plans, environmental requirements, mine closure, community development and employment of locals.

In Tanzania, the Mining Act (2010) is the principal legislation for the management of all mining activities in the country (URT, 2010). In this Act, relocation and compensation have been aligned with the requirements of the Land Act of 1999. This means that there should be fair and prompt compensation before local communities are relocated by a mining project, in terms of section 14(4d) of the Act. The aim of this Act (2010) is to ensure that involuntary resettlement is avoided and where it cannot be avoided, to ensure that locals in the area secure sufficient investment resources to be able to share in the project (URT, 2009).

According to the results of this paper, compensation and resettlement were explained by about 19.5% of all factors in the community. Based on the findings (Table 5), mining processes highly complied with compensation and resettlement of people in the community. Relocation of areas and compensation of assets was also realized in the community. It was noted more interestingly that the company was appreciated to offer employment to local people, avoidance of conflict through the demarcation of areas as well as procuring of goods and services available in the community that in some circumstances created a two-way closer relationship.

However, despite such recognition of compliance on some of the aspects as indicated by the study results, FGDs indicated a lot of complaints about inadequate recognition of traditional land uses and compensation for the loss of resource; access rights constituted major grievances within communities. Community responses indicated that some of the properties were not compensated for, such as crops. Even those which were compensated, were inadequately considered. The results show that some of the properties which were to be offered as payment for destructed assets, such as houses and land, were regarded by the mining company as part of the compensation process due lack of close monitoring by the government, local authorities and lack of awareness among local communities. Equally, Kumi (2014) observed that the nature of compensation to which an owner or lawful occupier may be entitled may include, without limitation to the cost of resettlement, the annual ground rent, and work the holder has carried out on the land and improvement. However, many concerns were being raised that the provision failed to consider livelihood restoration of caretakers or squatters in the project area of the land, who are considered to be normally hard hit by the project impacts.

World Bank (2004; 2009) also recognizes that people living in squatters are generally among the poorest people, and that resettlement programmes should direct special attention and support to them, to prevent further impoverishment. This is also in line with IFC performance standard which stipulates that there should be consultation and informed participation of affected persons and communities in decision-making processes related to resettlement or compensation (IFC, 2012). With respect to environmental management and social concerns, the mining policy of Tanzania recognizes that large scale mining could lead to relocation of communities and disruption of their livelihoods. It also recognizes that where relocation is inevitable, the government is considered responsible for valuing the land and properties of the affected communities, while the investor would be responsible for repayment of compensation, relocation and resettlement (URT, 2009). Despite these guidelines by the policy and thus the legal framework, there is however, a need to ensure that there is transparency in compensation procedures, proper valuations of land and other properties, adequate compensation rates and prompt payment of compensation (Amupadhi, 2017; Maliganya & Bengesi, 2018).

Measures for Mining Closure

In recent years, there has been an increasing recognition of the importance of mine closure that has been regarded as necessary at all stages of mining operations. The current best practice indicates that all mines should be designed for sustainable mine closure (Kumi, 2014; Muza, 2018). With respect to the measures for the mining closure component, the findings of this paper indicate that the community realized positive measures in terms of compliance towards the conditions to rehabilitate degraded land after operations as well as restoration of the environment for affected living organisms (plants and animals) in and out of the operational areas. Besides undertaking these measures, there was an occurrence of modified organisms in the surrounding areas (Table 5). This implies that upon closure of mining operations the issue of changes in genetic resources of living organisms should instantaneously be within the mining programme if genetic resources are to be preserved as before the establishment of mining activities.

While the study results indicated positive responses on compliance with respect to mine closure on some of the issues, FGDs and key informant interviews revealed that the community appeared to aspire for effective measures for sustainability after a project and after the mine closure in terms of land compensation and development of alternative livelihood options. The findings revealed further that the high expectations were due to the fact that community perception considered land as the only source of livelihood and the basis for sustainability. In this regard, the community members regarded themselves as the owners of the land who deserved additional payments as the only opportunity to alleviate poverty.

Social Accountability

Social accountability was one of the components perceived important for compliance by mining companies in the mining sector's regulatory framework of Tanzania. A localized social accountability becomes more crucial if the mining companies are to behave in a socially responsible manner. This entails creating an enabling environment that will enable local communities to practice their role in it (Rutenge, 2016). In light of this, the mining companies were perceived as legally bound to be socially responsible in compliance with various aspects which were affecting the local communities in the study areas. According to the study results, social accountability of the mining company was reported in different ways; apart from the extent of pollution as reported above, air pollution and noise pollution were given low attention in the society.

Variables such as demarcation of the mining area from the community area were positively realized as the means of avoiding conflict in the study areas. The results further showed that the mining company consulted local communities for their views on issues before the start of the project. The company also publicized its anticipated effects and benefits by posting posters in strategic public areas. In addition, public meetings were held with the affected parties and communities to explain the effects before mining operations began. In this regard, it can be generalized that less was socially accounted on pollution within the society and that the resolution of conflict through land interference and community awareness was well addressed within the mining programme.

However, in response towards enhancing social accountability, FGDs revealed that the local authorities were perceived to have less power to act on behalf of the local communities in pursuing their interests with the mining companies especially in the compensation process. This scenario has therefore put the mining companies to wield lots of power and hence not coming on to comply with legal requirements to response of contributing to the communities' priority needs. Kessy et al. (2017) revealed that building positive relationships between investors, government and local communities has been regarded as a fundamental aspect of natural resource management. Evidence showed that poor management of community expectations can contribute to social unrest and even civil conflicts as it has been witnessed in the Democratic Republic of Congo, South Sudan to mention some.

Sustainable Environmental Management System. In the context of the mining sector, laws are often formulated to regulate the relationship between actors and the environment. In Tanzania, the Environmental Management Act, 2004 is the principal legislation for the overall environmental management in Tanzania (URT, 2004). These laws, if effectively enforced, can play a vital role in regulating and protecting communities from adverse environmental and social impacts of mining, loss of land, biodiversity and natural wealth (Odeku, 2017). As a result of this, developing countries including Tanzania, have developed laws and institutions to regulate and monitor the extraction of mineral resources and their impact on the environment and people. However, the level of implementation, enforcement and compliance with those laws varies, and hence there are legal gaps.

Based on this, the findings (Table 5) show that the company's programme towards sustainable management system resulted into negative outcomes on the environment. The community realized highly unsustainable use of available natural resources (-0.879), also failure to abide by the conservation practices of plants and animals in surrounding areas (-0.859). In some cases, the system still performed less in the restoration of genetic resources. As a result new/modified organisms were released into the environment such as the replacement of natural forests with acacia trees which were not appreciated by the local communities in the area. In Zimbabwe, literature indicate further that several negative impacts have been produced for surrounding communities and the environment as a result of mining activities. The extraction of minerals, chiefly platinum, were physically damaging the environment and natural resources in terms of water resources, forests and wildlife on which local communities depended. This suggests that mining operations were still far behind in terms of abiding by the legal and regulatory frameworks' requirements towards enhancing sustainable mining practices in host countries, especially in Tanzania and possibly in most African countries (Chaumba, 2017).

Reliability Analysis

In order to measure the internal consistency as to show how a set of items is closely related, Cronbach's alpha was then calculated and results are presented in Table 6. The values for each component were generated using the following Cronbach's alpha relation in the box :-

> Cronbach's alpha (α) $= \dfrac{N * \bar{a}}{\bar{u} + (N-1) * \bar{a}}$
>
> Where:
> N is the number of items
> $\bar{a}$ is the average inter-item covariance among the items
> $\bar{u}$ is the average variance.

Table 6: Cronbach's Alpha values

Parameter	Factors				
	1	2	3	4	5
Mean	3.219	3.301	2.551	3.823	2.665
Cronbach's Alpha	.881	.807	.711	.801	.751
Squared Multiple Correlation	.562	.430	.357	.553	.354

The results (Table 6) indicate that the value of Cronbach's alpha among item components ranged from 0.711 to 0.881; this range is relatively high when compared to a minimum acceptable level of 0.7. According to Taber (2017), a value of around 0.70 or greater is widely considered desirable. Based on this argument, the research instrument employed in this study satisfied the measure of compliance towards mining activities in the community. Abstract Cronbach's alpha is a statistic commonly quoted by authors to demonstrate that test (Kaiser, 1970; Bengesi, 2013).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the discussion above, it may be argued that large mining companies are useful for Tanzania towards enhancing socio-economic development. However, discouraging challenges were still existing especially with respect to ensuring that a balance is created through compliance with respect to the distribution of benefits among its citizens, investors and the country at large. To the time of this research, communities in the study areas and the public in general continued to believe that the country has not done enough to ensure that the mining companies operated according to the governing rules in accommodating the interests of the local communities including small scale and artisanal miners.

While most of mining operations and programmes were complying on some issues such as compensation and resettlement; community awareness programs for rehabilitation of degraded land after operations; restoration of the environment for affected living organisms (plants and animals) in and out of the operational areas, however, the latter was less achieved on the ground. It was revealed that the programme encountered a failure to comply on issues regarding the management and control of both aerial and terrestrial pollutants, which in turn led to repeated reports of the occurrence of modified organisms in the surrounding environment. Indeed, the case also arose with less accountability for its measure within the society.

The paper argues for restructuring the issue of sustainable environmental management system within the programme before further implementation so as to reduce negative outcomes, including the prolonged decline of natural resources and unsustainable conservation practices for animals and plants. It is becoming increasingly clear that beyond regulatory reforms, there is need to strengthen capacity building among local communities and local civil society as a critical policy objective for improved mineral resource governance outcomes.

Since this paper was designed to assess whether large scale mining companies comply with the regulatory framework for sustainable mining practices, the paper makes useful contribution to the institutional theory. While the theory puts more emphasis on the need for mining companies to conform to the rules and regulations in relation to the management and use of mineral resources benefits, this paper provides for an avenue for theoretical and practical improvements as there are still existing gaps between formulated policies, rules and regulations and their actual practice on the ground, especially at the local level due to the disparities that still exist in terms of accessing accrued benefits.

This paper therefore puts more emphasis on the need for community based policies which are considered as a positive step towards creating common understanding of the mining sector implications on local people. Local communities require particular attention because the impacts of mining occur primarily at this level and thus need for social accountability. Therefore, we demonstrate that the success or failure of a resource based growth and development is country specific and requires the development of different and appropriately designed regulatory frameworks which are effectively enforced for compliance.

RECOMMENDATIONS

Since it was evident that some weaknesses were existing with regard to the policy and legal framework due to the existence of conflicting, un-harmonized and outdated policy documents, this paper recommends to the government to periodically update the legal framework in order to meet the current situation of the mining sector in Tanzania.

This paper has also observed that local communities were inadequately informed, consulted and involved in the governance process of the sector especially on associated opportunities and benefits. The paper therefore calls for the government and mining companies to have provisions for avenues for effective participation of various stakeholders including local communities proximity to the areas where mining operations take place for improved governance and thus associated benefits.

Unlike the provisions stipulated in the regulatory framework, compliance related to employment of local communities was not realized in practice, and there was apparent shortage of skilled and trained personnel among the locals to take full advantage of the job opportunities offered by the mining company. This paper recommends to the government and the mining companies that there is a need to train local people for the same to enhance their participation in the sector.

While transparency regarding the establishment of mining operations was considered important, it was also one of the hindrances of the attainment of sustainable mining practices which was perceived to have significant impacts on local communities in improving local livelihoods if well designed and otherwise if not carefully monitored. In view of that, the present paper recommends that there should be a need for harmonization of domestic legislations with respect to disclosure of mining sector contracts and payments for compensations. This should include, among others, elimination of confidentiality clauses in contractual agreements for the mining sector.

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INVASIVE *PROSOPIS JULIFLORA* REDUCES DENSITY AND SPECIES COMPOSITION OF CO-OCCURRING WOODY PLANTS IN THE LOWER MOSHI RANGELANDS, TANZANIA

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ABSTRACT

Although studies have indicated impacts of *Prosopis juliflora* in altering species composition, ecosystem processes, and soil properties in a large spatial scale,habitat-specific investigations assessing its effects on native woody plants is poorly studied. In this study, we assessed effects of *Prosopis juliflora* by comparing species composition attributes of native woody plants between Prosopis-invaded, and the adjacent uninvaded sites in Lower Moshi rangelands, Northern Tanzania. We used a plot technique to sample woody plants in the two sites. Within each plot, we recorded the abundance of woody species and calculated the diversity index, richness, evenness, and density of each woody species. A generalized linear model was used to test if the diversity, richness, evenness, and density of woody plant species vary between invaded and uninvaded sites. Results showed that uninvaded site had higher diversity, richness, and evenness of native woody species as compared to invaded site. We also found low density of woody species in invaded compared to uninvaded sites suggesting that high density of *Prosopis juliflora* impose more depressive effects on woody species. This study provides habitat-specific information for planning appropriate management and control strategies at the local scale to avoid further spread of the species to neighboring areas.

Keywords: Invasive plants, density, diversity, richness, woody species

INTRODUCTION

Most Alien invasive plants (AIPs) tend to rapidly evolve with adaptive mechanisms, making them strong competitors for space, light, water, and nutrients over the native plants (Higgins & Richardson, 2014). A prime example of such species is the Mesquite (*Prosopis juliflora* (Sw.) DC.), which is among the world's most highly invasive plants, native to the Americas (Lowe *et al*., 2004). This species is currently reported to invade sub-tropical and tropical habitats including arid rangelands (Ng *et al*., 2018). The plant species was introduced to the deserts of the subtropics and then to semi-arid tropics of Kenya, before invading parts of Tanzania two decades ago (Kilawe *et al*., 2017).

Encroachment of *P. juliflora* in rangelands is reported to threaten not only the ecological community characteristics but also the socio-economic wellbeing of the local people (Muller *et al.*, 2017; Ng *et al.*, 2018; Alvarez *et al*., 2019). Reported ecological effects include the reduction of co-occurring native biodiversity in

Hawaii, India, Kenya, Ethiopia, the United Arab Emirates, and South Africa (Alvarez *et al*., 2019), the displacement of habitats, the availability of palatable forages (Mukherjee *et al*., 2017) and the disruption of trophic interactions (Shackleton *et al*.,2015). Other effects include changes in soil properties (El-Keblawy & Al-Rawai, 2007), increased prevalence of malaria in human (Muller *et al*., 2017), and a reduction in habitat quality, crop, and livestock yields (Kumar & Mathur, 2014).

In Tanzania, the occurrence of P*. juliflora* was firstly reported in Mwanga town and Eastern Kahe ward in Lower Moshi Rangelands (Kilawe *et al.*, 2017). Further invasion of the species is also evident in Kijereshi Game Reserve (Pers. Observation), and some areas in Arusha, Mwanza, Morogoro, and Dar es Salaam regions (Kilawe *et al*., 2017). Although the introduction of the *P. Juliflora* to eastern Kahe was for charcoal, shade, and livestock forage, unfortunately, it has multiplied much faster than the rate at which it could be utilized (Kilawe *et al*., 2017). As a result, it has formed a dense stand alongside roads and railways, in grazing, and unattended farmlands.

Previous studies have indicated the impacts of *P. Juliflora* in altering species composition, ecosystem processes, and soil properties at landscape level (Shackleton et al., 2014, 2015), while habitat-specific investigation regarding its effects on native woody plants is poorly documented.In this study we assessed the effects of *P. Juliflora* by comparing diversity, evenness, richness, and density of native woody plants between Prosop is-invaded, and the adjacent uninvaded sites in Lower Moshi rangelands in northern Tanzania. By comparing Prosopis-invaded and uninvaded sites we can detect effects of *P. juliflora* and provide valuable information for control and management of the species(Shackleton *et al*., 2015).

MATERIALS AND METHODS

Study area

We conducted this study in the Eastern Kahe ward, 30 km south-east of Moshi town in Kilimanjaro Region. It is located at 3037'S 37027'E, and it constitutes part of Lower Moshi Rangelands at the foothill of Mount Kilimanjaro in northern Tanzania. Precipitation occurs between March and May, and ranges from 275-500 mm/year. The area is characterized by gentle sloping plains at 700 m above sea level (Rudengren, 1981). The soil varietals include alluvial loam fluvisols, gleysols, vertisols, and saline soils. Despite its semi-arid condition, underground flowing water supports diverse plant communities ranging from shrubs and bushes to tall trees. The area is predominated by scattered woody native plants such as Sennasiamea (Lam.) H.S. Irwin & Barneby, Newtonia buchananii (Baker) G.C.C. Gilbert & Boutique, Ficussycomorus (Miq.) C.C. Berg., and Markhamialutea (Benth.) K.Schum. The Prosopis-invaded area in Kahe is close to Rau Forest Reserve and Kilimanjaro National Park in the north-west and Mkomazi National Park in the south-east

Data collection

A stratified random sampling approach was used to characterize the study area into invaded experimental and uninvaded control sites. The uninvaded and invaded sites were located as close as possible to each other to ensure similarities in elevational gradient, climatic condition, and soil profile. Sites in proximity were chosen, to minimize the probability of pre-existing differences in vegetation between the two sites. We selected forty 10 m^2 plots established at an interval of 100 m along four transects positioned in invaded patches and forty 10 m^2 plots in the adjacent uninvaded site. In total, 80 plots were established during the study. Plots with at least one *P. juliflora* were considered as invaded whereas those without any *P. juliflora* were regarded as uninvaded habitats. The Prosopis-invaded and uninvaded habitats were chosen based on similarities in elevational gradient, climatic conditions, and soil profile. We used sisal twine and wooden pegs to mark the plot edges (Muturi *et al*., 2013) and a tape measure to estimate the interval between plots. To ascertain the effects of *P. juliflora* on the woody plants, we recorded abundance and richness of all plant taller than 0.5 m in each plot. Within each plot, we recorded the abundance of woody plants and calculated diversity index, richness, evenness, and density. These were used as measures of effects of *P. juliflora* on woody species composition between invaded and uninvaded sites. The same comparative approach between invaded and uninvaded sites done by Hejda *et al*., (2009) and Kumar & Mathur, (2014) was applied in this study. All plots were sampled during the growing season from April to June 2016. Ally woody plants encountered during the survey were taxonomically identified according to van Wyk & van Wyk, (2013).

Data analyses

Before performing statistical analysis, we calculated the Shannon diversity, evenness, and species richness of woody species in each plot using Vegan R package1.15-1 (Oksanen *et al*., 2008). We also calculated the density of woody plants as the number of individuals divided by the unit plot area. Then, we used univariate generalized linear models (GLMs) with a Gaussian error structure to test if diversity and evenness of native woody plants vary between invaded and uninvaded sites. Poisson distribution was used to test for differences in native plant richness between in the two sites. Additionally, we used GLM with Gaussian distribution to test if the density of *P juliflora* has an influence on the density of the native woody species. For each response variable, a maximal model was generated, and the significance of each predictor was assessed by likelihood ratio tests (LRTs) using lrtest () function of lmtest R package (Hothorn et al., 2018). The reported $\chi 2$ values refer to LRTs conducted between the output of each univariate model and its null model. The proportion of the explained variation for each model fit was also assessed with the pseudo-R-squared of sqPearson by using RsqGLM() function in modEvA R package (Barbosaet al., 2014). All statistical analyses were performed using R version 3.5.2 (R Core Team, 2018).

RESULTS

A total abundance of 511 woody plants were observed of which 110 were sampled from invaded site while 401 were from uninvaded site. We found that the diversity of native woody species varies significantly between sites ($\chi 2$ = 42.981, df = 1, p < 0.001). The mean diversity of native woody species (± Standard deviation (SD) was 0.617 ± 0.083 higher in uninvaded than invaded sites (t = 7.449, df = 79, p < 0.001. the R-squared for this model was 46%. We also found that the richness of woody species between invaded and uninvaded sites varies significantly ($\chi 2$ = 17.454, df = 1, p < 0.001). The average richness of woody species in the uninvaded site (± SD) was 0.658 ± 0.162 higher than that of the invaded site (z = 4.068, df = 79, p < 0.001. The R-squared for this model was 22%. Further results showed a significant difference in evenness between invaded and uninvaded sites ($\chi 2$ = 20.241, df = 1, p < 0.001). The uninvaded site had higher mean evenness (± SD) of woody species 0.658 ± 0.162 than the Prosopis-invaded site (z = 2.830, df = 79, p < 0.001, The R-squared of this model was found to be 46%. Apart from that, we found that the density of native woody species varies significantly with a density of *P. juliflora* ($\chi 2$ = 42.974, df = 1, p < 0.001. At the high density of *P. juliflora* the mean density of woody species (± S.D.) was noted to decrease at an average of -0.120 ± 0.017 trees ($t = -7.231$, $df = 79$, $p < 0.001$). The R-squared for this model was found to be 34%.

DISCUSSION

Several studies have explained the effects of AIPs in displacing and reducing richness, and density of native under story (El-Keblawy & Al-Rawai, 2007; Mukherjee *et al*., 2017). Our findings showed adverse effects linked to *P. juliflora* invasion on the richness, evenness, diversity, and density of woody plants at micro scale. This suggests that *P. juliflora* is associated with a reduction of plant composition (Kumar & Mathur, 2014; Shackleton *et al*., 2015). Present findings are consistent with those obtained by Shackleton *et al*.,(2015), Muturi *et al*., (2013) and Kumar & Mathur (2014) who found low species richness and diversity of natives in Prosopis-invaded compared to uninvaded plots. Another study conducted in the Jamnagar District of Gujarat state of India on effects of *P. juliflora* on plants found that the density of endangered *Commiphora Wightii L*. (Guggul) decreased with increasing density of P. juliflora (Kumar & Mathur 2014). Similarly, Mukherjee *et al*., (2017) found an increase in spatial extent and dominance of *P. juliflora* replacing the dominant natives such as *Acacia nilotica (L.) Delile, Mitragynaparvifolia Roxb*., and *Salvadoraoleoides Decne*. Several factors could explain the observed variation by the present study. The high ability of *P. juliflora* to produce allelo chemicals imposes depressive effects associated with displacement, low establishment, and low growth rate of the native plants (El-Keblawy & Al-Rawai, 2007; Getachew *et al*., 2012). The fact that *P. juliflora* has relatively few natural enemies also presents an added advantage for its dominance over other woody species. Another possible factor includes its slow decomposition and accumulation of leaf litter below *P. juliflora*, which may result in accumulation of toxic substances in the soil layers which inhibits proper germination and growth of native woody plants (El-Keblawy & Abdelfatah, 2014).

Low evenness in the invaded plots suggests that *P. juliflora* has the potential to affect how native woody species can be distributed in space. The dominance of *P. juliflora* over native woody plants in Prosopis-invaded site could be explained by differences in traits associated with reproduction, and dispersal abilities, seedling establishment and survivorship, genome size and phenotypic plasticity, growth rate, and biotic resistance (El-Keblawy and Abdelfatah, 2014). Also, Shiferaw *et al.* (2004) showed that *P. juliflora* has a high ability to re-sprout quickly from the stumped/ damaged stems, making it a robust and aggressive competitor.

We also found that at low density of P. juliflora, density of woody plants was higher and vice-versa. A study by Maundu *et al*. (2016) assessed effects of *P. juliflora* on native plants in South Africa revealed an inhibitory effect of *P. juliflora* which hinders the germination and growth of co-occurring woody plants. Thus, the depressive effects of *P. juliflora* on the woody plants in Kahe could be attributed by its inhibitory and allelopathic potential to displace native plants. They form impermeable thickets that reduce agricultural, and grazing areas for livestock and wildlife (Mwangi & Swallow, 2005).

CONCLUSION AND RECOMMENDATIONS

In overall,this study concludes that there was a low diversity, richness, evenness, and density of native woody species between the Prosopis-invaded and uninvaded plots suggesting a sizable depressive effect of *P. juliflora* on native woody species. This is because of the expansionist nature of the species, more grazing lands, farmlands and neighboring natural areas are likely to be affected if the situation is left unattended. Therefore, we recommend for the urgently appropriate control and management measures to curb further *P. juliflora* invasion are needed. Also, we recommend a long-term vegetation monitoring to determine spatial-temporal changes of *P. juliflora* and native flora and fauna.

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ASSESSING MANAGEMENT AND THREATS OF THE INVASIVE PLANT PARTHENIUM WEED ON BIODIVERSITY CONSERVATION IN TANZANIA

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ABSTRACT

Increasingly, invasions of *Parthenium hysterophorusin* East Africa threaten biodiversity conservation and small-holder livelihoods. In Tanzania, particularly in the Arusha region, *P. hysterophorus* is threatening to encroach into the Arusha National Park (ANAPA) and to date, little research has been done on an effective, environmental-friendly management of this plant. We assessed *P. hysterophorus* distribution within ANAPA and adjacent villages. We also tested *Desmodium intortum, Lablab purpureus,* and *Medicago sativa* in a competition experiment to control *P. hysterophorus*. Our results showed that albeit some adjacent villages are invaded, ANAPA is yet not affected. But, this species' rapid expansion threatens ANAPA'secology and biodiversity. *P. hysterophorus* was observed growing in grazing areas, maize and banana fields in the villages, and along the Momela tarmac road and other small rough roads. High densities of *P. hysterophorus* were recorded in maize fields, along roadsides, and at lower elevations. In our competition plotexperiment, *P. hysterophorus* total fresh biomass was > 45% lower when grown with two or three suppressive plat species than when it was grown in monoculture or *M. sativa* alone. In either combination, *L. purpureus* showed higher suppressive effects compared to other test plant species. Therefore, our results show that P*. hysterophorus* can be controlled if suppressive forage plant species are maintained in our rangelands. In addition, an invasive species survey within the ANAPA and its border zones should be conducted regularly in order to prevent the invasion.

Keywords: biodiversity, competition, Invasive, *parthenium hysterophoru*s, suppressive plants.

INTRODUCTION

Parthenium hysterophorus is an exotic invasive plant species which is widely distributed in many parts of the world with deleterious impact on biodiversity and environments (Kaur *et al*., 2014; Tanveer *et al*., 2015; Terblanche *et al.*, 2016). It is a pioneer species that invades rapidly disturbed and degraded areas (Brunel *et al*., 2014; Kaur *et al*., 2014). It is native to North and South America (Usharani & Raju, 2018). It produces light weighted seeds (ca. 10,000–25,000 per plant), which are disseminated by wind, water, and human activities (Brunel et al., 2014; Kaur *et al.*, 2014). The species takes four to six weeks to grow from seeds to mature plants, depending on local soil type and weather conditions (Kaur *et al*., 2014; Timsina *et al*., 2011). In a recipient ecosystem, *P .hysterophorus* releases allelochemicals, which inhibit growth of neighbouring co-existing plants. It is also toxic to animals if it is eaten in large quantities as forages, however, it is seldom eaten (Kaur *et al.*, 2014). When people repeatedly in contact with *P. hysterophorus* they develop dermatitis, skin allergies, fever, asthma and respiratory illness especially when its pollen is inhaled (Terblanche *et al*., 2016). Increasingly, invasion of *P. hysterophorus* in sub-Saharan Africa decreases the quality of agricultural lands, grazing fields, and rangelands (Clark & Lotter, 2011; Terblanche *et al*., 2016). The species causes agricultural and biodiversity losses (Tanveer *et al*., 2015), displaces indigenous plant species, change ecosystem structure, function, and soil properties of the invaded habitats (Brunel *et al*., 2014; Nguyen *et al.*, 2017).

In Tanzania, *P. hysterophorus* (known as 'gugu karoti' in Swahili) was first reported in 2010 in the Arusha region (Clark &Lotter, 2011). Presently, its invasion has reached other four regions: Manyara, Kilimanjaro, Geita, and Kagera. It has invaded agricultural fields, road sides, and rangelands in these regions. Its invasion threatens crop production, human wellbeing, livelihood, biodiversity, ecosystem services, and forage availability (Ojija *et al*., 2019). Due to its rapid invasions and negative impacts on biodiversity and smallholders' livelihood, urgent management to prevent its spread into protected areas and agro-ecosystems is required. Tropical Pesticides Research Institute (TPRI) in Arusha has been investigating the ability of Mexican leaf eating beetles (*Zygogramma bicolorata*) to control *P. hysterophorus* in Tanzania.

Despite its known impacts on biodiversity and rapid spread, there has been little research to investigate management approaches of *P. hysterophorus* and its threats to protected areas in Tanzania. Furthermore, limited studies have been conducted to assess and/or establish the current distribution of *P. hysterophorus* in protected areas particularly in Arusha region. Understanding the current distribution of the invasive is important so that control efforts can be directed to those areas, which are already invaded or vulnerable to invasions. This study aimed to assess (i) the current distribution of *P. hysterophorus* within and outside the ANAPA and (ii) its management using potentially suppressive forage plant species. Arusha National Park was surveyed because it is more vulnerable to the invasions compared to other protected areas. It is also found in Arusha region, where *P. hysterophorus* invasion is rapidly expanding (Kilewa & Rashid, 2014). Therefore, the possibility of *P. hysterophorus* being inside or at the border zones of ANAPA is high compared toother protected areas.

MATERIAL AND METHODS

Study area

A field survey was conducted inside and outside ANAPA to assess current *P. hysterophorus* distribution between January and June 2018. The ANAPA is located between 3°15’ S and 37°00’ E within Arusha region, Tanzania (Fig.1).

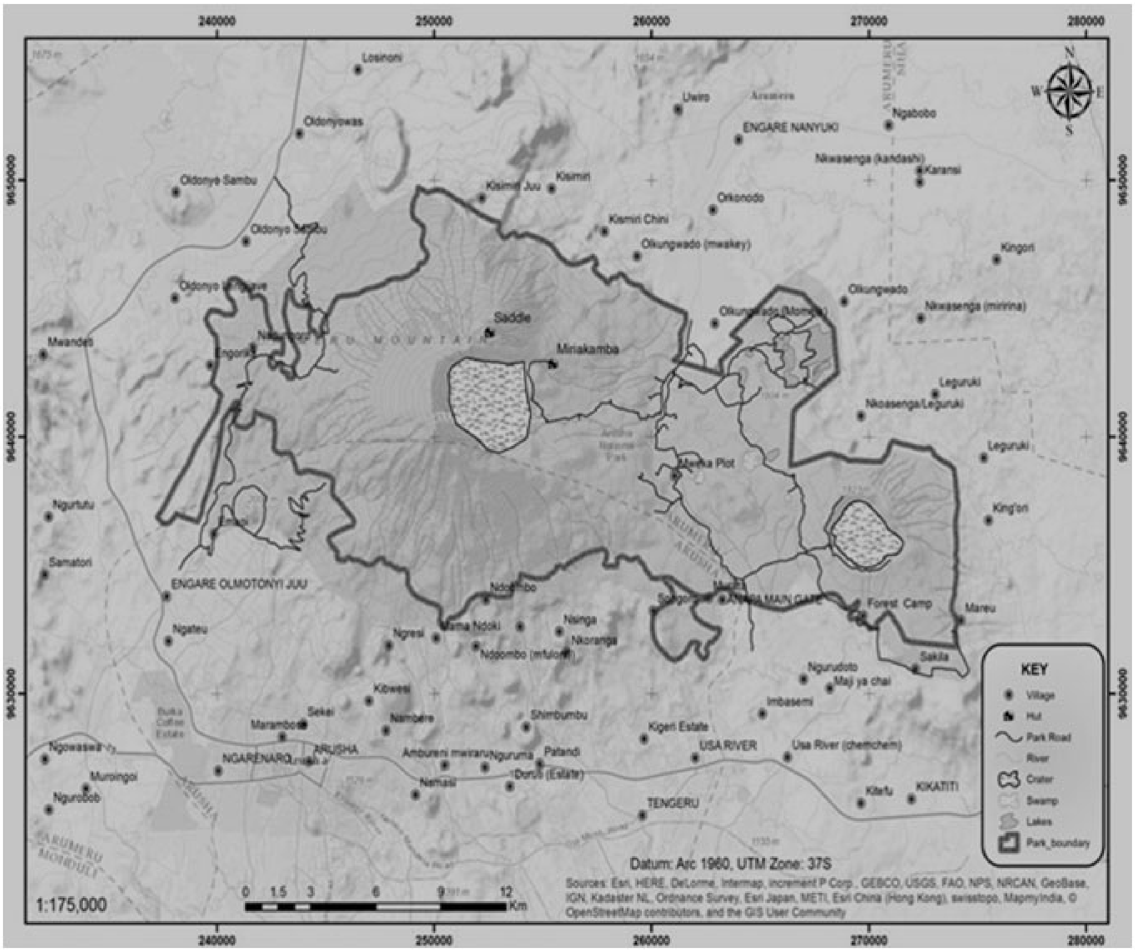

Fig.1. Map of the study area

Data collection

We used vehicle and motorcycle to conduct surveys inside and outside the ANAPA . The roadside survey method was used (Christen & Matlack, 2006; Wabuyele *et al*., 2015). Areas surveyed outside the park were the border zones and adjacent villages. The road was scanned on both sides, recording the locations of *P. hysterophorus* using Garmin etrex20 GPS. Outside the ANAPA, stops were made after every 30 to 50 m to scan the presence of *P . hysterophorus*. Inside the park the stops were made at interval of 1 km. We recorded the presence data including elevation, land use type, and density per 1 m^2 quadrat. The density was visually estimated as high, medium, and low when there were > 4, 3-4, and 1-2 *P. hysterophorus* seedlings in our 1 m^2 quadrat, respectively. A roadside survey method was used as *P. hysterophorus* prefers to grow along road verges (Thapa et al., 2018; Wabuyele *et al*., 2015).

Assessing management of *Parthenium hysterophorusvia* suppressive plant species

We investigated competitive ability of selected legume forage plant species Desmodium intortum, Lablab purpureus and Medicago sativa to suppress *P. hysterophorus* growth vigor. These plants demonstrate three main characteristics, soil improver, weed competitor, cover crop or ground cover, and ability to fix atmospheric N, which make them possibly appropriate for management of *P. hysterophorus* in protected areas (Kariuki *et al.*, 1999). Desmodium intortum (greenleaf desmodium) and M. sativa (*lucerne*) have been widely grown in eastern and southern Africa to feed livestock (Ngondya *et al.*, 2016). Lablab purpureus (Lablab) is grown for seed and forage production (Amole *et al.*, 2013). Its seeds are consumed by some animals (Maass *et al.*, 2010). Seeds of *P. hysterophorus* were obtained from TPRI, D. intortum and M. sativa were purchased from Kibo Seed Company Ltd. in Arusha, and *L. purpureus* were obtained from the Nelson Mandela Institute of Science and Technology (NM-AIST). Experiments to assess their suppressive effects on *P. hysterophorus* seedlings growth were conducted in field plots (1 m^2) at NM-AIST Tengeru campus ($3^0$24.149' S and $36^0$47.790' E, 1197 m a.s.l). Twenty-five seeds of *P. hysterophorus*, *D. intortum, M. sativa*, and *L. purpureus* were sown in 5 plots in monoculture (control) and mixture. Seedlings were allowed to grow at a constant density in 55 planting (Table 1).

Table 1: Plot experimental planting design with *P. hysterophorus* and suppressive plant species. Respectively, P, M, D, and L stand for *P. hysterophorus*, *Medicago sativa* (*lucerne*), *Desmodium intortum*, and *Lablab purpureus*. S0, S1, S2, and S3 refer to levels of suppressive species richness, respectively.

P. hysterophorus grown with and without suppressive plant species				Suppressive plant species grown alone
PS_0	PS_1	PS_2	PS_3	
Plot experiment				
4P	4P/6M	4P/6M/6D	4P/6M/6L/6D	6M
	4P/6D	4P/6M/6L		6L
	4P/6L	4P/6L/6D		6D

Each plot was irrigated every day in the morning with 4 liters of water. Growth vigour of *P. hysterophorus* in response to suppressive effects of competitive forage plant species was assessed by measuring total fresh biomass of its 50-day-old seedlings harvested from each plot. *P. hysterophorus* total leaf chlorophyll (total Chl) content was also determined. The biomass was measured using an analytical balance. Total Chl contents was extracted according to Hiscox and Israelstam, (1979) and Ngondya *et al.*, (2016) with some modification. The total fresh biomass and Chl content were compared across suppressive species planting combinations using one-way ANOVA. We confirmed the normality and homogeneity of variance using a Shapiro-Wilk test and Levene's test respectively. The post-hoc Tukey-Kramer HSD test was used to separate the means at $p \leq 0.05$. The statistical software used was Origin (2013) version 9.0 SR1 at a significance level of $\alpha = 0.05$.

RESULTS

Current distribution of *Parthenium hysterophorus* within and outside ANAPA

During our survey within the park we did not locate *P. hysterophorus*. However, it was recorded in some villages such as King'ori, Maleu, Napoco, Ngongongare, Ngurudoto, Oligilai, and Sakila neighboring the ANAPA (Fig 2).

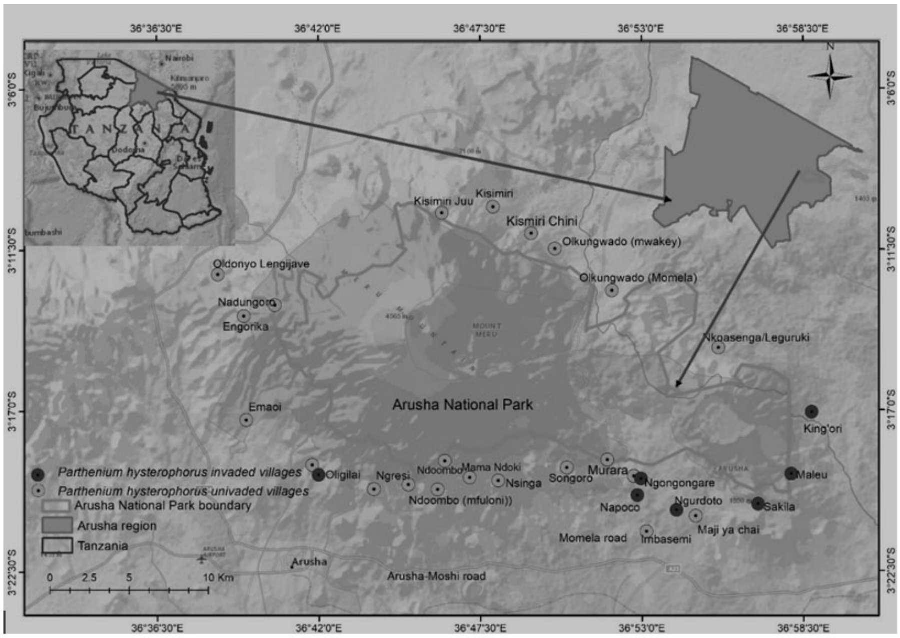

Fig. 2. Map showing current distribution of *P. hysterophorus* within and outside ANAPA

P. hysterophorus was observed growing in grazing areas, maize and banana fields, along the Momela tarmac road, and other small rough roads. High *P. hysterophorus* density was recorded in maize field, along roadsides and at lower elevation (Fig 3). It was also seen growing in anthropogenic disturbed habitats such as landfills or dumping ground found in villages and roadsides. Invaded villages were located few distances away from Arusha-Moshi road which is highly invaded with *P. hysterophorus.*

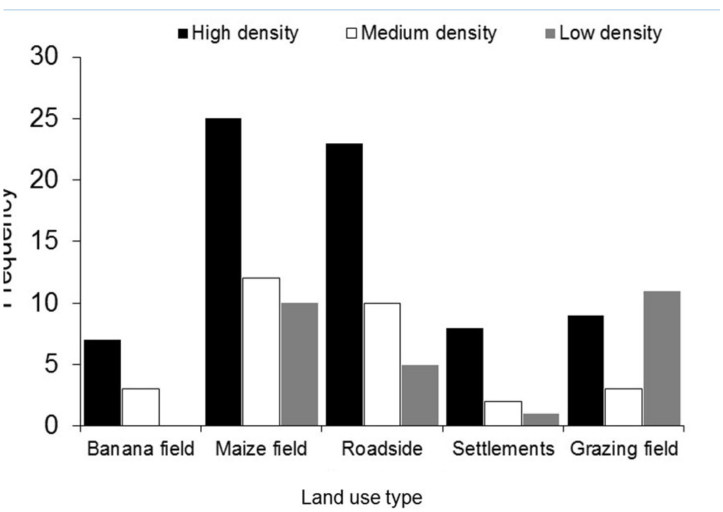

Fig.3. Frequency of occurrence of *P . hysterophorus* in different land use types

Management of *P. hysterophorus* using suppressive forage plant species

Total fresh biomass of *P. hysterophorus* seedlings was significantly different between suppressive species planting mixture ($F_{7, 32}$ = 12.38, p <0.0001, Fig. 4). Total biomass was reduced by > 42% when grown with two or three suppressive species than when it was grown in monoculture. Also, when *P. hysterophorus* was grown with a single suppressive species, *D. intortum* (PD: 23.4±2.2 g, p = 0.0048) or *L. purpureus* (PL: 17.3±1.5 g, p < 0.0001) the total biomass was reduced by >36% compared to when grown alone or with *M. sativa* species (PM: 27.3±2.6 g, p = 0.1016). In each planting combination, *L. purpureus* showed higher suppressive effects on *P. hysterophorus* seedlings growth vigour (Fig 4).

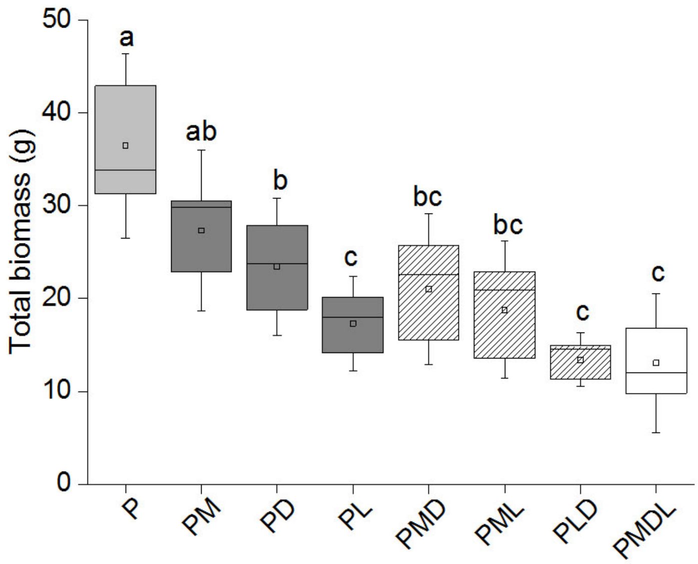

Fig. 4. Mean (±SD) total fresh biomass of *P. hysterophorus* seedlings when grown alone (light grey box), and with one (dark grey boxes), two (dashed boxes) or three (white box) suppressive plant species. Boxplots show the mean (a square within boxes) and ranges from 25% and 75% quartile, and the tips of the whiskers show standard deviation. Boxes with dissimilar letter (s) are significantly different by Tukey's HSD test at p ≤ 0.05. P = *P. hysterophorus*, M = *M. sativa*, D = *D. intortum*, and *L* = *L. purpureus*.

Total leaf chlorophyll content (Chl) of *P. hysterophorus* differed significantly between suppressive plant species diversity (F(4, 20) = 48.36, p< 0.0001, Fig 5). When *P. hysterophorus* was grown witha single species *D. intortum* or *L. purpureus*, its total Chl was > 44% lower than when it was grown alone or with *M. sativa* (PM: p< 0.0001, PL: p< 0.0001, Fig 5). *P. hysterophoru*s leaf Chl was reduced by > 40% when grown with two suppressive species (PMD: p< 0.0001, PML: p< 0.0001, PLD: p< 0.0001, Fig. 5) than when it was grown in monoculture. In addition, the leaf Chl of *P. hysterophorus* was 69% lower when grown with three suppressive plant species than when it was grown in monoculture (0.005±0.0, p< 0.0001) or in PM, PD, PL and PMD planting combinations (Fig 5).

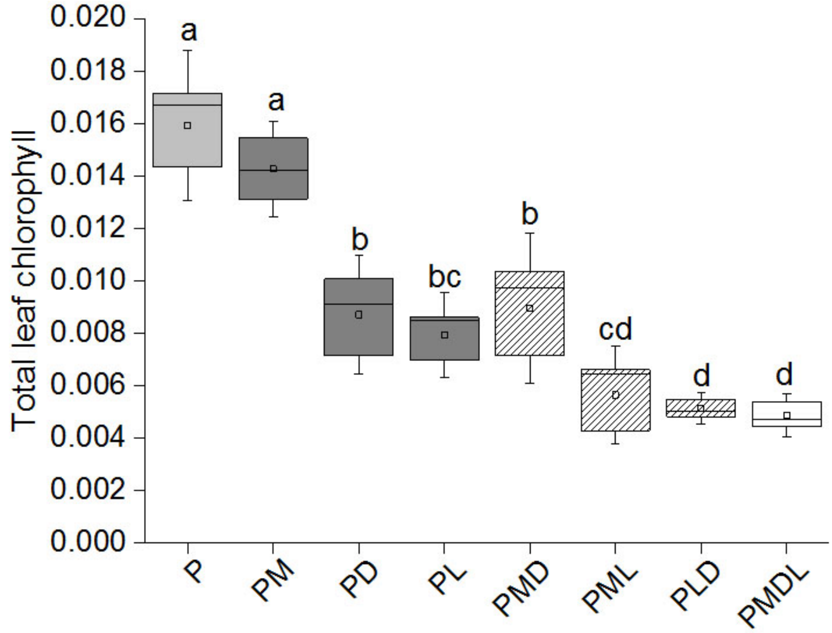

Fig. 5. Mean (±SD) total leaf chlorophyll content of *P. hysterophorus* seedlings when grown alone (light grey box), and with one (grey boxes), two (dashed boxes) or three (white box) suppressive plant species. Boxplots show the mean (a square within boxes) and ranges from 25% and 75% quartile, and the tips of the whiskers indicate standard deviation. Boxes with dissimilar letter (s) are significantly different by Tukey's HSD test at $p \leq 0.05$. P = *P. hysterophorus*, M= *M. sativa*, D = *D. intortum*, and L= *L. purpureus*.

DISCUSSION

The study revealed that *P. hysterophorus* is currently invading villages adjacent to ANAPA Arusha and along the Momela road which is entering the park. This invasion is threatening biodiversity and ecological integrity of the park. Although the ANAPA is not currently invaded, human and tourism activities can accidentally spread *P. hysterophorus* seeds into the park or around its border zones. ANAPA being located at higher elevation might be a reason of why it is not invaded by *P. hysterophorus* now. Results from this study has indicated that, high *P. hysterophorus* invasion was recorded at lower elevations. Moreover, villages' socio-economic activities (e.g. cultivation, grazing, and collection of fodder) adjacent to the park border zones might easily promote the dispersal of *P. hysterophorus* seeds into the park. *P. hysterophorus* may also spread into the park as a contaminant by travellers, in particular as seeds in their belongings, (Gervilla *et al*., 2019). Vehicles from Arusha and other areas may carry *P. hysterophorus* seeds in mud adhered to the tyres into the park and /or its border zones (Von Der Lippe & Kowarik, 2007). Tourists and staffs may as well carry the seeds in mud adhered to their shoes, clothes or other belongings into the park. Additionally, the Momela road which is invaded with *P. hysterophorus* also increases the chance of spreading of *P. hysterophorus* seeds into the park. This is because the roadsides are preferential areas of *P. hysterophorus* and the starting points for its invasions into adjacent surroundings (Christen & Matlack, 2006; Johnston & Johnston, 2004; Von Der Lippe & Kowarik, 2007; Wabuyele *et al*., 2015). The study also found that high invasion of *P. hysterophorus* was associated with human activities. Thus, human activities at the park border zones should be controlled in order to prevent unintentional introduction of *P. hysterophorus*.

The growth vigour of *P. hysterophorus* seedlings was negatively impacted by suppressive forage species. Results indicated that, *L. purpureus* outperformed other suppressive species because its presence in the planting mixture reduced *P. hysterophorus* seedling growth. For example, the suppressive species combination i.e., PMLD, PML, PDL, and PL reduced *P. hysterophorus* growth as its seedlings displayed a lower biomass and chlorophyll content which is in agreement with Khan et al., (2013, 2010), Shabbir *et al*., (2013), and Zheng *et al*., (2015). In addition, these parameters were constantly low across high numbers of suppressive forage species. This suggests that high plant diversity in grassland may reduce ecosystem invasibility (Knops *et al*., 1999). Since ecosystem invasibility is influenced by the available resources in the habitat (Perkins et al., 2011; Tracy *et al*., 2004), increasing abundance and diversity of the most (i.e.L. purpureus) and lesser (i.e. *M. sativa*) effective forage species may reduce ecosystem vulnerability to *P. hysterophorus* invasions as there is a complete resource utilization (Knops *et al*., 1999; Connolly *et al*., 2018). Thus, maintaining diversity of forage suppressive plant species could ensure ecosystem health and stability.

Moreover, in this study the large ground cover and broad leaves of *L. purpureus* shaded the juvenile seedlings of *P. hysterophorus*; and perhaps reduced their growth due to structural features, similar to findings of Tamado *et al*., (2002) and Khan *et al*., (2010, 2013). Hence, we suggest that management methods to mitigate *P. hysterophorus* using competitive forage species should target its rosettes (juvenile stage). Though *D. intortum* is recommended for conservation as ground cover and pasture (Kariuki et al., 1999; Maina et al., 2006), in this study it was indicated that it can also be used to control *P. hysterophorus*. However, in order to enhance *D. intortum* suppressive ability against *P. hysterophorus*, it may be mixed with some effective suppressive fodder plants or grass species such as *L. purpureus*, Digitaria eriantha, Urochloa mutica, and Pennisetum clandestinum as it is likely to grow better in mixed stands (Aganga & Tshwenyane, 2003; USDA NRCS, 2012). In addition to its extensive ground cover, the greater suppressive efficacy of *L. purpureus* was probably due to its higher stem height, root, and biomass compared to other species. The study highlights that biological control through competitive plants is an approach with further potential for managing *P. hysterophorus*, and it may benefit smallholder farmers (Pratt *et al*., 2017) while protecting the environment from *P. hysterophorus* (Van der Laan *et al*. 2008; Khan et al. 2013). Nevertheless, to effectively control *P. hysterophorus*, seeding suppressive plants must be done before the emergence of rosettes and immediately following pulling of mature *P. hysterophorus* seedlings to create appropriate conditions (e.g. enough space, nutrients, water, and light) for quick establishment of suppressive species

CONCLUSION

The suppressive plant method represents a low-cost and nature-friendly management technique, and if *L. purpureus*, and other effective suppressive fodder plants are planted together in invaded pastures in addition to suppressing invasive, may promote wildlife and livestock health and production. Also, it is recommended that the park border zones should be monitored regularly for *P. hysterophorus* and being removed immediately when it is seen.

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PREVALENCE OF GASTROINTESTINAL PARASITES IN FREE RANGING BUFFALOES IN ARUSHA NATIONAL PARK, NORTHERN TANZANIA

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ABSTRACT

Gastrointestinal parasites including round worms, tape worms, cestodes and coccidian species are of health significance in the survival of young animals both livestock and wildlife. A study was conducted in Arusha National Parkin 2012 to establish the infestation and diversity of internal parasites species in buffaloes, which might be shared with livestock. Five dung samples were randomly collected from five different buffalo herds. A total of 25 buffalo dung samples from five herds were collected in five different locations in the park and analyzed for internal parasites. Sedimentation test was used to identify eggs of internal parasites with the aid of a light microscope and reference of parasites identification guidebook. Egg Count per Gram (EPG) was performed using MacMaster slide to quantify for the parasites load for selected worm species. Using sedimentation test, about 13 species were identified to genus level including Bunostomum, Eimeria, Fasciola, Fischoedeuris, Gastrothylax, Oesophagostomum, Ornithobiasharzia, Ostertagia, Paramphistomum, Schistosoma, Strongyloides, Toxocara and Trichostrongyloides,and multiple infestation was observed in all buffalo samples. A number of other nematode eggs were observed but were not identified because it was beyond the scope of the identification guidebook. The average EPG for each of the selected parasite species were Bunostomum (250±135; n=4), Eimeria oocysts (225±177; n=8), Oesophagostomum (275±225; n=10), Ostertagia (300±129; n=4), Strongyloides (62±16; n=2),Trichostrongyloides (392±431; n=6). Identification to species level was difficult basing on morphological examination suggesting for further analysis using molecular techniques. Many of internal parasites observed in a cross sectional surveys are also common in livestock, it is likely that some of the parasites are probably shared between livestock as a spill over and spill back. With such a high species diversity of internal parasites, it is possible to act synergistically and cause clinical condition particularly in calves and affect the recruitment rate of the respective buffalo population.

INTRODUCTION

Gastrointestinal parasites including round worms, tapeworms, cestodes and coccidian species are of health significance in the survival of young animals both livestock and wildlife, and have an influence in the recruitment rates in the respective populations. Gastro-intestinal parasitic infections are recognized as one of the major obstacles in profitable large ruminant production in subtropical and tropical countries including Tanzania. The parasites cause considerable economic losses due to: (1) animal health disorders as direct effects of parasite infection in the gastrointestinal tract (e.g. weakness, diarrhea, anorexia, anemia, intestinal obstruction, etc.), and indirect effects which may manifest as an increasing susceptibility to secondary infection (Hendawy, 2018), (2) reduce livestock productivity as indicated by a slower growth rate, low milk production, low body condition score (BCS), and the fatality in young animals (Fitzpatrick, 2013), as well as (3) additional therapeutic cost.

African buffalo (*Syncerus caffer*) is one of the large herbivores and in free ranging in Tanzania that has high interaction with livestock due to migration and livestock incursion in protected areas (Munang'andu *et al*., 2012). High interaction between wildlife and livestock that originate from different locations in the country and even from across the border into an ecosystem or one habitat is likely to be a proponent of introducing diseases sourced from different ecosystems into a new habitat thereby exposing animals to parasitic infections they would otherwise have never been exposed to. In the Arusha national park, livestock incursion is very common due to shrinkage of rangeland in community areas because of crop farming, which force livestock keepers to illegally take their livestock into protected areas. In free ranging little information is available on internal parasites in buffaloes but more work has been carried out in domesticated water buffaloes in middle east (Karwan *et al.*, 2017; Nurhidayah *et al*., 2019). From the past experience of observing high livestock-wildlife interaction in Arusha National Park, it was paramount to investigate parasitic diseases of wildlife with a view of generating baseline data for use in trace-back systems during disease outbreaks and the translocation of animals from one ecosystem to the other. However, in the present study, we investigated the presence of only endoparasites in buffaloes, of which some might be shared with livestock in order to obtain baseline data on the nature of internal parasitic infections present in buffaloes in the ecosystem. Internal parasites load and species diversity can be a good indicator of buffalo population performance in the ecosystem and can be used for future comparison with the intra-species from different ecosystems in Tanzania.

MATERIALS AND METHODS

Study area

A study was conducted in Arusha National Park in 2012 to establish the infestation and diversity of internal parasites species in buffaloes, which might be shared with livestock. Random sampling was used to immobilize five buffaloes from five locations for collection of dung samples from five different buffalo herds (Fig. 1).

Dung sample analysis

A total of 25 buffalo dung samples from five herds were collected in five different locations in the park and analyzed for internal parasites. Sedimentation test was used to identify eggs of internal parasites with the aid of a light microscope and reference of parasites identification guidebook. Egg Count per Gram (EPG) was performed using MacMaster slide to quantify for the parasites load for selected worm species.

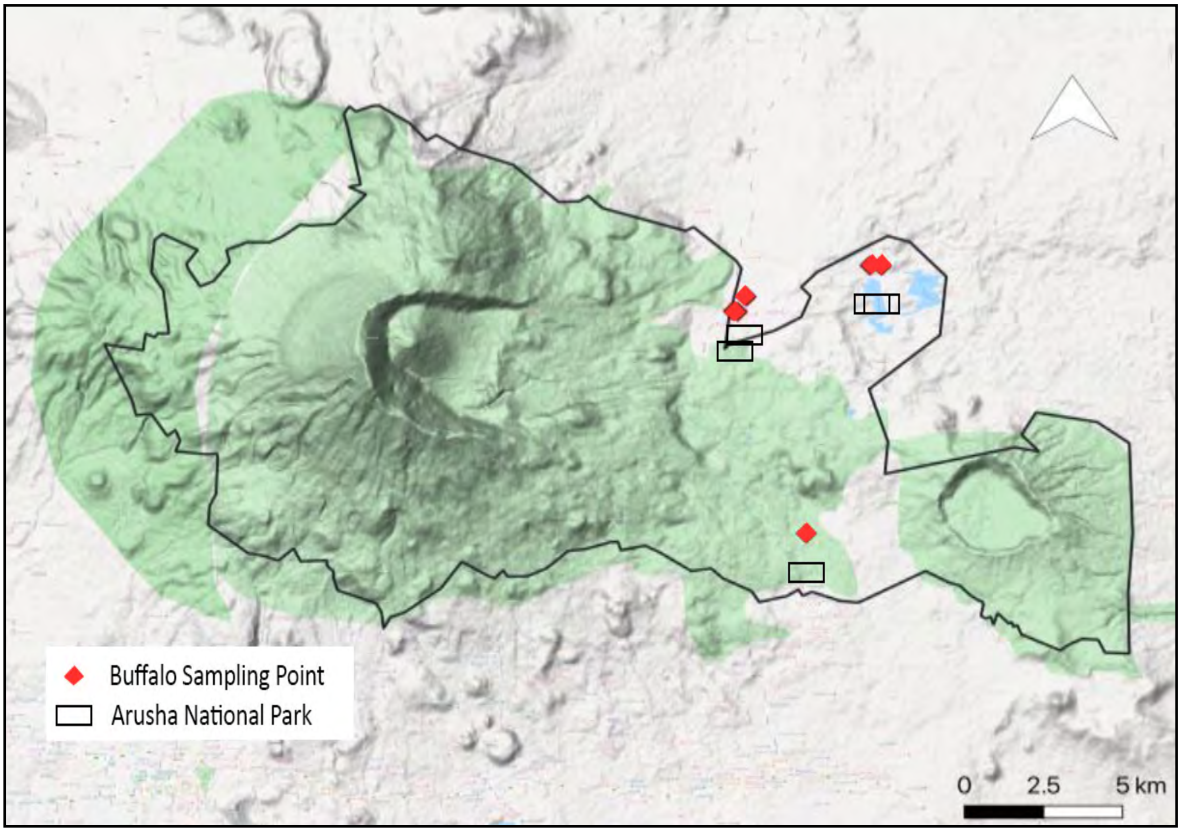

Fig. 1. Sketch map of Arusha National Park showing buffalo sampling sites

Fig. 2. A buffalo is being blind folded in preparation for dung sample collection and other valuable samples

RESULTS

A total of 25 buffalo dung samples from five herds were collected in five different locations in the park and analyzed for internal parasites. About 13 species were identified to genus level including Bunostomum, Eimeria, Fasciola, Fischoedeuris, Gastrothylax, Oesophagostomum, Ornithobiasharzia, Ostertagia, Paramphistomum, Schistosoma, Strongyles, Toxocara and Trichostrongyloides. All buffalo dung samples had multiple infestation, and other nematode eggs were not identified because it was beyond the scope of the guidebook. The average EPG for each of the selected parasite species were Bunostomum (250±135; n=4), Eimeria oocysts(225±177; n=8), Oesophagostomum (275±225; n=10),Ostertagia (300±129; n=4), Strongyles (62±16; n=2),Trichostrongyloides (392±431; n=6).

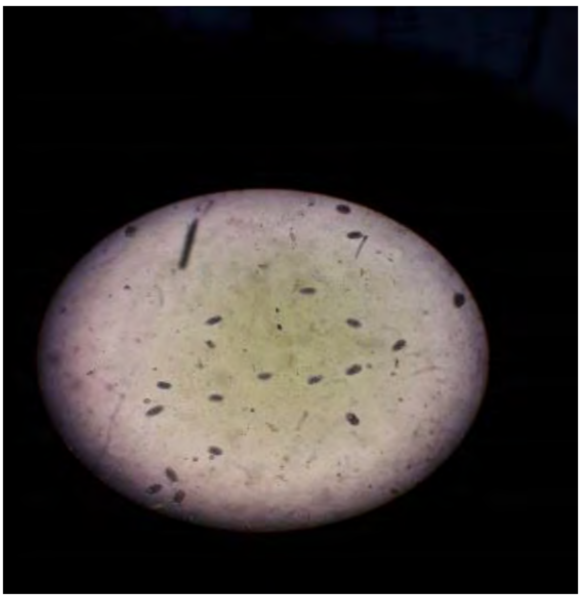

Fig. 3. Microscopic picture showing Strongyle eggs.

DISCUSSION

The results of this cross-sectional study were in line with observations made on studies of nematode infection described in water buffaloes (Bubalus bubalis) (Nurhidayah *et al.*, 2019). This observation suggests that the small home range of buffaloes in Arusha National Park resembles a game ranch or meaning that wildlife in this small protected area are semi-domesticated with high interaction with livestock. In general, both prevalence and parasitic burden were low indicating a sub clinical infection. Strongyle eggs were the most prevalent nematodes found during microscopic examination, which could be easily identified from the grape-shaped embryos inside an oval-shaped-eggs. which may belong to Haemonchus, Ostertagia, Trichostrongylus, Mecistocirrus, Cooperia, Nematodirus, Oesophagostomum, Chabertia and Bunostomum. Most species of Strongyles were cosmopolitant and often found in small and large ruminants among livestock.

In the current study, identification of internal parasites to species level basing on morphological examination of eggs could not be conducted due to the absence of the third stage larvae (L3), which can easily be obtained during the coproculture process. Therefore, we are suggesting for further analysis using molecular techniques or in combination with coproculture to get hold of L3 larvae. Many of the internal parasites observed in this cross sectional study survey are also common in livestock, and since livestock incursion is very common in this particular park, it is likely that some of the parasites are probably shared with livestock as a spillover and spillback.

In general the body size of adult buffaloes in Arusha National Park (ANP) is very small both for males and females compared to body size of adult buffaloes from other protected areas like the Serengeti ecosystem, Manyara-Tarangire ecosystem, Mikumi-Selous ecosystem, Ruaha-Rungwa ecosystem and Katavi-Rukwa ecosystem to mention just few major ecosystems. The small body size of adult buffaloes in ANP can be explained to be probably due to inadequate forage because of small protected area with literary no dispersal areas. The protected area is surrounded by farmers who keep few zero grazed dairy cattle and goats or few free ranging local cattle and small stock. Lack of dispersal areas is also denying buffaloes possibility of immigration and emigration, therefore, there is no gene flow, hence inferior gene in the isolated buffalo population. Presence of high diversity of internal parasites might be contributing to nutritional deficiency and stress coupled with inadequate forage in the rangelands.

Previous studies have shown that although African buffaloes are resistant to a number of endo and ectoparaites, when stressed they succumb to clinical symptoms with noticeable mortality especially in calves (Fyumagwa *et al*., 2013). Small herd sizes of ANP buffaloes might be partly contributed by low recruitment rate as a result of calf mortalities, however, this is a mere speculation.

CONCLUSION

Multiple worm infestation in buffaloes can act synergistically and cause clinical diseases particularly in calves and affect negatively the recruitment rate of affected populations. Lack of gene flow from outside because of human settlement as a physical barrier is affecting the genetic vigor of the isolated population. Therefore, it is recommended that if possible, some buffalo bull from healthy ecosystems should be introduced to raise the genetic vigor and diversity of this isolated small population.

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COMPARISON OF DIRECT AND INDIRECT METHODS APPLIED TO ESTIMATE ELEPHANT ABUNDANCE IN THE MIOMBO WOODLANDS OF SOUTH-WESTERN TANZANIA

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ABSTRACT

The use of direct methods such as Total Counts (TC) and Systematic Reconnaissance Flights (SRF) to estimate large mammal numbers is common practice in major protected areas (PAs), while the use of indirect methods involving indices such as tracks and signs is also widespread. Unfortunately, whilst conservation actions are dependent on population estimates obtained from these surveys, they are rarely cross-checked, partly due to high cost involved in undertaking them concurrently. Here, we compare density estimates obtained from aerial surveys and dung counts collected concurrently in Katavi National Park (KNP) in western Tanzania between August 2014 and October 2014 to enable comparisons between the two methods and to correct estimates based on the use of an indirect method in low density areas where direct counts are economically unfeasible. We also compare estimates of relative abundance for African elephant obtained from dung counts collected in various PAs with varying degrees of protection across the landscape to assess the correlations between different land use designations and elephant abundance. We found evidence of a strong correlation between density estimates obtained from aerial and ground counts suggesting indirect methods could be used to supplement direct methods. As expected, we found density estimates to be higher in fully protected areas (National Parks and Game Reserves) and lower in Lesser Protected Areas (Open Areas). Based on 2014 countrywide aerial surveys that indicate a significant drop of African elephant population, we estimate a minimum of c.430 individuals (about 4% of the total individuals counted in the Ruaha-Rungwa ecosystem) to have been missed in Piti East and Rungwa South Open Areas and call for futures surveys to be extended to all lesser protected areas using indirect methods validated here.

Keywords: Census techniques, Direct count, Elephant count, Indirect count

INTRODUCTION

Knowing population and distribution of animals is a vital prerequisite for conservation (Kumara et al., 2012; Ransom *et al.*, 2012a; Anderson et al., 2013; Rouse *et al*., 2014). The lack of population estimates for species hinder long-term wildlife conservation across different scales and make site level prioritization more difficult to achieve (Western *et al*., 2009; IUCN, 2013; Songhurst *et al*., 2015; Shoko et al., 2015; Chase et al., 2016). Estimation of wildlife densities in low population and/or low visibility areas where direct surveys are inefficient or impossible to implement has been a major challenge to wildlife managers for a long time (Jachmann, 1991; Whitehouse *et al*., 2001). Inadequate and /or lack of surveys in many low-density areas may account for significant numbers of animals being undetected, since direct surveys targe thigh density areas expected to have large proportions of wildlife populations (e.g. TAWIRI, 2009; TAWIRI, 2014). A variety of methods exist for surveying wildlife in high- and low-density areas, but often the calibration between techniques has been inadequate (e.g. Jachmann, 1991; Whitehouse *et al*., 2003; Anderson et al., 2013; Hema *et al*., 2013).

Direct surveys (involving counting of actual individuals) are the gold standard for population estimates, with a variety of methods in common use in Africa including foot transects for small and accessible areas (Jachmann, 1991), vehicle counts for small to medium sized areas (Burnham *et al*., 1980; Foguekem et al., 2010) and aerial counts for large areas (Douglas-Hamilton, 1996; Melville *et al.*, 2008; Foguekem et al., 2010), all often based on distance estimates (Buckland *et al*., 1993; Koenen *et al*., 2002; LaRue *et al*., 2007; Ransom et al., 2012a). Aerial surveys are perhaps the most popular of all the other methods because of its reliability and consistency of the results when survey guidelines are followed consistently (Foguekem et al., 2010; Gandiwa *et al*., 2013). Furthermore, the method covers large areas quickly, and is capable of surveying areas where access on the ground is difficult (Blac *et al*., 2007). However, aerial surveys and direct measures in general are often impossible when small or cryptic species are involved (Craig, 1993; Ransom *et al.*, 2012a), in areas of thick vegetation (Barnes, 2001; Newson *et al*., 2013), or where densities are too low to make flights economically viable. Additionally, aerial surveys locate animals at a single instance of time, whilst animals may move and use much larger areas, requiring a degree of smoothing to help obtain accurate spatial estimates (cite).

In situations where direct surveys are not practical, indirect survey methods such as faecal counts (Short, 1983; Merz; 1986; Barnes & Jensen, 1987; Fay, 1991; Barnes *et al*., 1995), genetic techniques based on fur or dung samples, track surveys, etc., are an alternative option. These methods have the additional advantage that because tracks and signs can last a long time, indirect surveys integrate density over time and whilst seasonal movement patterns may impact population density estimates, indirect methods are far less susceptible to short-term fluctuations in movement patterns than direct census methods. For elephants and other large mammals, dung counts have been widely applied to estimate population density in forest systems (Craig, 1993; Barnes, 2001; Blanc *et al*., 2007; Kéry & Schmidt, 2008; Archaux *et al*., 2012; Newson *et al*., 2013), or in more open habitats where aerial surveys are not possible to implement. The increasing use of indirect methods in low density areas makes it important to validate and calibrate estimates generated against estimates derived from direct survey methods (e.g. Jachmann, 1991; Hema *et al*., 2013; Schlossberg *et al*., 2016), to reduce uncertainties that wildlife managers have on the validity of dung counts in general (Hema *et al*., 2013).

African savannah elephant populations numbered about one million as recently as the 1970s (Douglas-Hamilton, 1987; Milner-Gulland & Beddington, 1993). Between 1970s and 1980s, these populations were significantly reduced across their range (Douglas-Hamilton, 1987), and renewed poaching since 2005 led to the killing of an estimated 30,000 elephants annually (UNEP *et al*., 2013; Wittemyer *et al.*, 2014), with the current remaining continental population estimated at about 375,000 individuals (Chase *et al*., 2016). In Tanzania, estimating wildlife numbers is a routine undertaking (once every three years on average) and a pivotal responsibility of the Tanzania Wildlife Research Institute (TAWIRI), a government parastatal research organization under the Ministry of Natural Resources and Tourism (MNRT). Using a combination of Total Count (TC) and Systematic Reconnaissance Flight (SRF), TAWIRI routinely covers seven major ecosystems known to harbor large mammal (herbivore) populations. An indirect method such as dung counts is also used in a few isolated low-density areas (TAWIRI, 2014). The recent countrywide population estimates of about 43,500 African elephant indicates a marked decline of about 60% compared to about 109,000 individuals in 2009 (TAWIRI, 2014). However, these estimates (both the 2009 & 2014) are largely derived from high elephant density areas covering about 17% of the elephant range in Tanzania while a further 18% of the range (MNRT, 2007), considered low density areas is largely uncounted suggesting a possible underestimation of elephant populations. Surveying wildlife abundance in low density areas using aerial surveys has been constrained by the effects of low density on estimators largely due to imperfect detection (Barnes, 2002; Kéry & Schmidt, 2008; Archaux *et al*., 2012), and in such circumstances, dung counts may be the most appropriate technique (Jachmann, 1991; Barnes, 2001).

A key elephant population in Tanzania occurs in the Ruaha-Rungwa and Katavi-Rukwa ecosystems, which has also suffered an estimated 76% decline in recent years (TAWIRI, 2014). Due to some inconsistencies in carcass ratios (e.g. TAWIRI, 2014), the scale of decline in this ecosystem has been questioned and a suggestion made that some elephants may have moved into neighboring low-density areas that are not routinely counted/censured (TAWIRI, 2009; TAWIRI, 2014; TAWIRI, 2015). Using counts from an indirect method and simultaneous aerial surveys of high-density areas, I calibrate population estimates from direct and indirect survey methods, and estimate the contribution of low-density elephant populations to an ecosystem wide population estimate. I also compare relative abundance of elephant in the fully protected areas (FPAs) and lesser protected areas (LPAs) within the two connected ecosystems of Katavi-Rukwa and Ruaha-Rungwa to assess the influence of the difference conservation management regimes on species abundance. The LPAs are multiple land use areas and we expect them to have low densities as compared to FPAs which exclude human practices. We hypothesize that there is a strong correlation between density estimates from the two methods.

MATERIALS AND METHODS

Data collection

Our analyses involved dung count datasets collected across the landscape between August and October in 2014 in Katavi National Park (KNP) and in six PAs (Ruaha and Katavi National Parks, Rungwa and Lukwati Game Reserves as well as Rungwa South and Piti East Open Areas) with different land-use designation categories and aerial datasets which were simultaneously undertaken by TAWIRI as part of the routine countrywide major ecosystem's censuses as detailed below.

Dung count datasets in the various PAs with varying degree of protection

Prior to the actual surveys, we carried out pilot surveys in each individual PAs to select an appropriate survey method, identify areas considered potential elephant range within each of them and identify logistical problems (Hedges & O'Brien, 2012). Furthermore, we also used historical distribution maps from aerial censuses for the past decade (within NPs and GRs) to identify elephant range areas within each PA and restricted our random surveys in these areas due to time and resource constraints (Maisels et al., 2013; Schlossberg *et al*., 2016). To obtain dung densities across the various protected areas across the landscape with varying degree of protection, we used the earlier developed standard technique for dung surveys (Burnham *et al*., 1980; Jachmann & Bell, 1984; Barnes & Jensen, 1987; Jachmann, 1989; Buckland *et al*., 1993; Hedges & Lawson, 2006). This involved creating a 10 km by 10 km grids for the larger PAs (Rungwa Game Reserve, Ruaha and Katavi National Parks) and 5km by 5km for the smaller PAs (Lukwati Game Reserve, Rungwa South and Piti East Open Areas). Transects were oriented from east to west (for each PA) perpendicular to roads and major rivers to improve precision (Maisels *et al*., 2013)(Fig 1). Within each PA, we randomly located and walked one transect in each of the selected 10 grids per PA. For large and small PAs, we consistently maintained a distance of about 20 km and 10 km respectively between transects to reduce risks of spatial autocorrelation (Hema *et al*., 2011). An average effort of 10 random transects of 1 km long each were applied in each PA making a total of 60 transects (60 km) surveyed for all PA categories combined.

Actual data collection took place towards the end of the dry season (August to October 2014) and coincided with TAWIRI aerial censuses in the two ecosystems. Wet season surveys are impractical in this landscape, due to extensive inundation and resulting poor access. The survey team consisted of three people who walked in a straight line on a pre-determined compass bearing, with the principal observer walking along the center line while the recorder walked behind and scanned for dung on either side of the transect line. All dung within sight of the transect lines was recorded. When we encountered dung piles, we measured perpendicular distance (cm) between the transect line and the dung pile with a tape measure and well as recording the distance along transect with a GPS. Our analysis strategy assumed that dung on the line was highly detectable, with detection probability decreasing with increasing distance from the line (Thomas *et al.*, 2010). Only those dung-piles that fell in the decomposition stages A to D (Table 1) defined by Barnes & Jensen (1987) were included in the subsequent analyses.

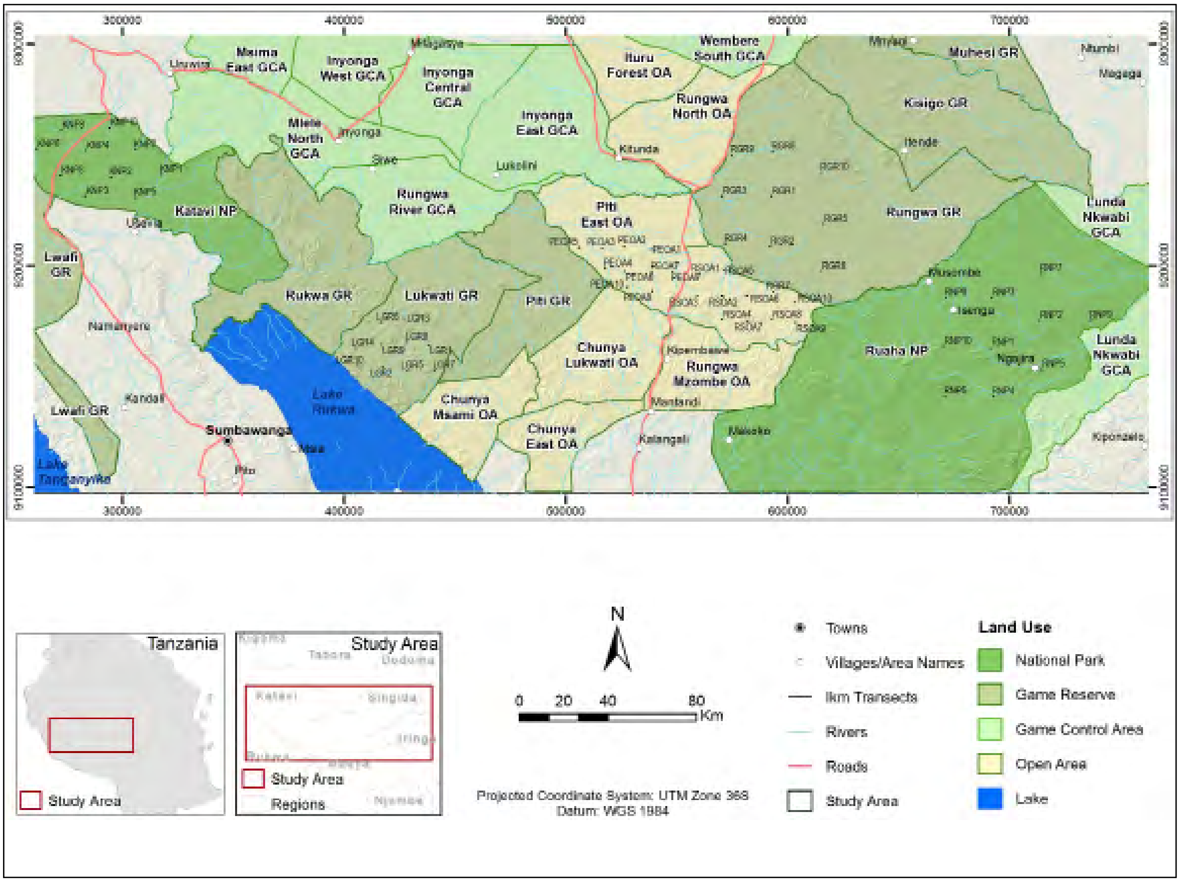

Fig. 1. Transect layout in the six protected area categories in the study area

Table 1: Dung Category Status based on decomposition stage (Source: Barnes & Jensen, 1987)

Category	Description
A	Boli intact, very fresh, moist, with odour
B	Boli intact, fresh but dry, no odour
C	Some of the boli have disintegrated; others are still recognizable as boli
D	All boli completely disintegrated; dung-pile now forms an amorphous flat mass
E	Decayed to the stage where it would be unlikely to be detected at a range of two metres in the undergrowth

Dung count estimates against aerial estimates

One week after the aerial censuses were completed in 2014, the ground crew used permanent transects that were flown by the aerial census crew and established a grid of 51 transects (1 km each) along aerial routes in KNP (Fig 2), with distance between start and end of subsequent transects set at 1 km intervals. Actual dung collection protocols followed the one described earlier in section 5.2.1.1 (second paragraph).

Aerial datasets

We obtained census datasets from the TAWIRI database stemming from two popular methods namely SRF and TC (Norton-Griffiths, 1978). The latter method adhered to standards technique for the MIKE (Monitoring of Illegal Killing of Elephant) programme (Douglas-Hamilton, 1996; Omondi *et al.*, 2005; Craig, 2012) following earlier developed protocols (Norton-Griffiths, 1978; Douglas-Hamilton *et al.*, 1994; 1996). The detailed methods and results of this survey are presented in the final census official report (TAWIRI, 2014). Only a fraction/ subset of the entire dataset (51 transects of 1 km long each totaling to 51 km sampling effort combined) involving the area of overlap in KNP was used in the subsequent analyses (Fig 2).

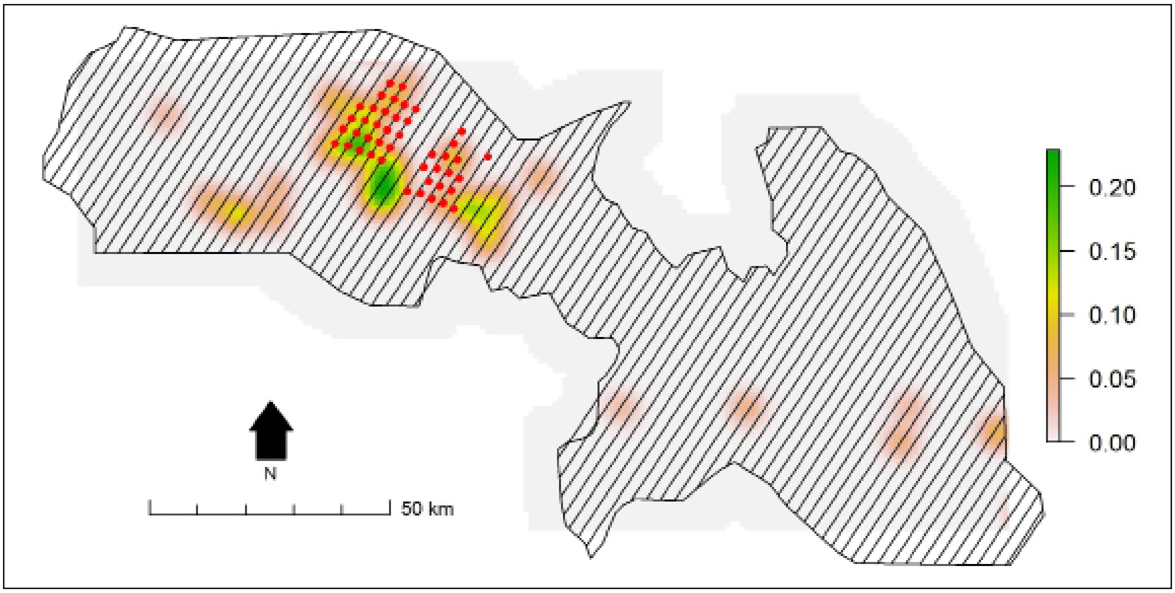

Fig. 2. Areas where aerial and dung surveys overlapped in Katavi National Park. The red dots denote surveyed grids along permanently established Aerial transect routes (transect lines set at 45 degrees angle and 2.5 km apart) for routine large mammal consensus within the boundaries of KNP. The background represents smoothed Aerial estimates (density per km^2) across KNP and beyond (Katavi-Rukwa ecosystem).

DATA ANALYSIS

Establishment of decay and defecation rates

Converting dung density estimates to elephant population estimates requires the estimation of dung decay and defecation rates. Due to insufficient time to establish actual production and decay rates specific to KNP, we used estimated production and decay rates established previously in the neighborhood landscape, using the average decay rate for wet and dry seasons (Barnes, 1980). Here,we used an average of wet and dry season production rate of 21 dung piles/ day (Barnes, 1980), and the mean decay rate (81.82 days, SE = 6.68 days) from fourteen estimates of dung disappearance time for different seasons, habitats and sites (Maisels *et al.*, 2013). To convert dung to elephant density, we only included dung piles not in a late stage of decomposition ‘’class A-D’’ (Buckland et al., 2001).

Comparison of aerial and dung count density estimates

We used a combination packages (“rgdal”, “raster”, “Distance” and “lmodel2”) in R (R Core Team 2016) to validate dung estimates obtained from the two methods above. Firstly, we computed estimates from dung and aerial methods using counts collected from the two techniques. To obtain density estimates from dung, we first computed the overall detection function (fitted as a Half normal Cosine 2, 3, 4, 5) adjustments using “Distance” package and corrected the observed dung counts by the detection probabilities. To estimate transect level densities, we estimated the overall dung densities for each PA using Distance package in R and converted to actual individuals using decay and defecation rates obtained as described above. Simultaneously, using aerial survey data, we generated a smoothed estimate of elephant density across KNP using a 2-d Gaussian smooth with standard deviation of 2.5 km (thereby recognizing that exact elephant positions at the point in time the survey occurred are overly precise). Finally, we matched each ground transect with the overlying aerial survey subunit and plotted the two estimates against each other to obtain a correlation.

Estimating missed individuals during the 2014 aerial surveys in Rungwa South and Piti East Open Areas

To obtain numbers of elephant that may have been missed by excluding Rungwa South and Piti East Open Areas (OAs) from the routine aerial censuses (TAWIRI, 2014) involved fitting a type II regression model using “lmodel2” package, Version 1.7-2 (Legendre et al., 2015) on the two estimates obtained from aerial and dung using R (R Core Development Team 2016). The model computes a simple linear regression using ordinary least squares (OLS), major axis (MA), standard major axis (SMA), and ranged major axis (RMA) (Legendre et al., 2015). Subsequently combined relative density estimates obtained from dung counts in the two LPAs and divided by the best fit estimates and then multiplied by estimates considered best fit obtained from the aerial estimates. Best fit estimates are chosen for two reasons i) it is on the best fit line, and ii) because the corresponding density estimates in the x-axis will be a probable (limited) overestimation from the aerial survey and dung estimates. Finally, the number of individuals missed from the two OAs was computed by multiplying densities estimates obtained from Rungwa south and Piti Open Areas with their respective areas (in km^2).

Relative density estimates in various protected areas in the study area

We estimated relative densities for each PA category using DISTANCE version 6.2 release 1 software package (Thomas *et al.*, 2010). To achieve a reliable dung density estimate, we truncated data to the nearest 95% of sightings (Kumara *et al.*, 2012). We judged the fit of four possible alternative models (Half-normal, Uniform, Hazard rate and Negative exponential each against three expansion series (cosine, simple polynomial and Hermite polynomial) to each specific dataset using Akaike's Information Criterion (AIC) value and goodness of fit tests generated by the program DISTANCE, and selected Half-normal cosine as the best model (Kumara *et al*., 2012). Using DISTANCE program, we subsequently generated encounter rate, average probability of detection, cluster dung densities, cluster size and dung density (using the Half-normal cosine model).

RESULTS

Comparison of density estimates from the two methods

Density estimates for the two methods indicates a strong correlation suggesting the reliability of estimates from both techniques ($r = 0.745$, $N = 51$, P-value < 0.001). Although there is a strong relationship between the two density estimates, the linear relationship indicates that smoothed density estimates obtained from aerial counts underestimates elephant populations at low densities and overestimates at higher density areas relative to dung counts,Figure 3 (a). The under and overestimation of density estimates are revealed by circles on the left and right sides of the one by one line in Figure 3 (a) respectively. On the other hand, the actual estimates from aerial estimates from a set of PAs (Ruaha National Park, Katavi National Park, Rungwa Game Reserve and Lukwati Game Reserve), indicate a more coherent relationship between the two estimates suggesting an agreement between the two method seven with a few data points involved, Figure 3 (b).

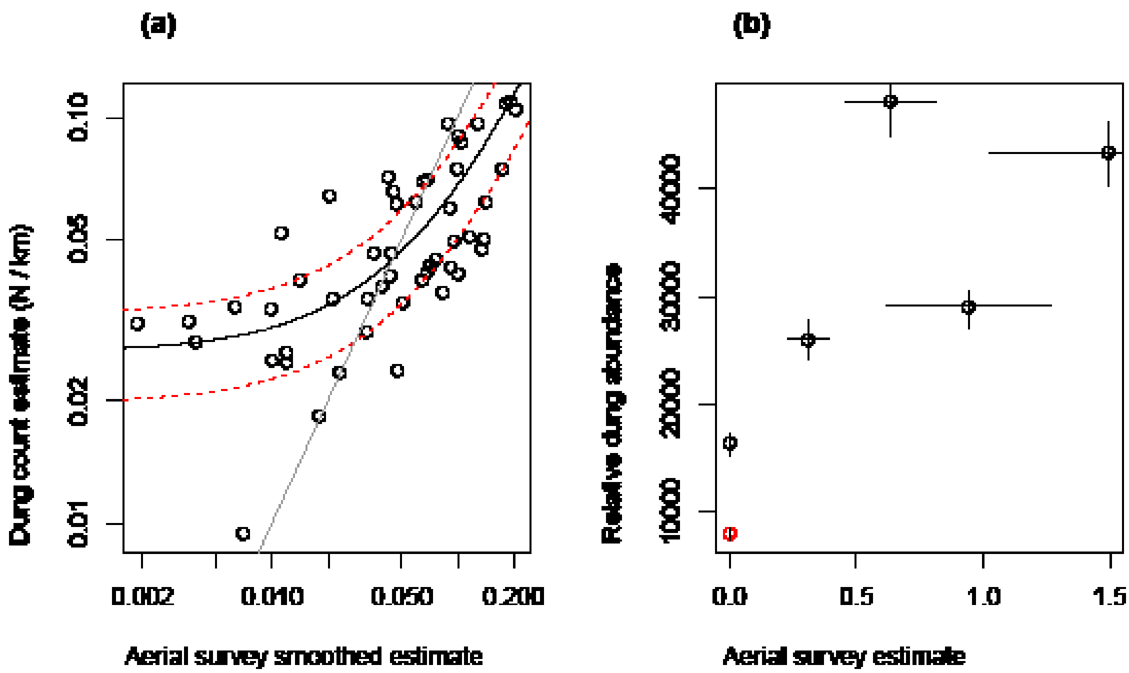

Fig. 3. Correlation of estimates from the two surveys. 5.3(a) denotes the correlation between Dung counts estimates (Individuals per km^2) against smoothed estimates from aerial surveys, 5.3(b) Denotes the correlation between the actual Dung count estimates (Individuals per km^2) against the actual estimates with error bars from Aerial Surveys. The under and overestimation of density estimates are revealed by circles on the left and right sides of the one by one line in Figure 3 (a) respectively.

Missed individuals by aerial counts for not surveying Rungwa South and Piti East Open Area

Our analysis estimated c. 430 elephants to have been missed (for excluding Piti East and Rungwa South Open Areas) based on the relative density of dung in these two areas and the estimated population in 2014.

Elephant abundance in the three different PA categories

The analysis further observed the highest dung densities of the African elephant to be in strictly protected areas namely Ruaha and Katavi National Parks (Table 2). Game Reserves (Rungwa & Lukwati) which are also under the strictly protected category were the next highest. Open Areas category which are least protected had the lowest density estimates overall (Table 2).

Density estimates in the three different PA categories

We observed the highest dung densities of African elephant to be inRuaha and Katavi National Parks (Table 2). Game Reserves (Rungwa & Lukwati) are also strictly protected category and had the next highest densities. LPAs comprising of Open Areas category had the lowest density estimates overall (Table 2).

Table 2. Computed relative density estimates of African elephant in the three different protected area categories using a Half-normal cosine model. Aerial density estimates where obtained from the TAWIRI, 2014 census report.

Designation estimate	Relative Density	%CV	df	95% C.I	Aerial density
Ruaha NP	48,2036.82	604	42,	169 – 55,100	4,210
Katavi NP	43,2645.73	595	38,	660 – 48,417	3,128
Lukwati GR	26,029	7.52	358	22,473 – 30,193	1,090
Rungwa GR	29,0965.35	385	26,	192– 32,321	2,801
Rungwa South OA	16,2966.73	187	14,	272 – 18,607	Not surveyed
Piti East OA	7,899	10.16	107	6,460 – 9,657	Not surveyed

DISCUSSION

Our analysis reveals that relative to dung counts, aerial counts underestimate individuals at low densities (fine scale) and overestimate them at higher densities (broad scale)Figure 3(a), which is contrary to findings of earlier studies (Bayliss & Yeomans, 1989; Whitehouse et al., 2001; Jachmann, 2002;Kéry & Schmidt, 2008; Koneff *et al.*, 2008; Archaux et al., 2012; Ransom, 2012b; Newson *et al.*, 2013; Schlossberg *et al.*, 2016). Furthermore, we found evidence of a strong correlation between density estimates obtained from aerial and ground counts using dung indices suggesting indirect methods could accurately be used to supplement direct methods. Hema *et al.*, (2012) called for the verification for the validity of dung counts for monitoring large herbivores at a large site that already has a well-established monitoring program such as the study area.

All survey methods have advantages and disadvantages but disadvantages can be minimized if multiple methods are used in parallel. For example, direct ground counts produce estimates with large variances and wide confidence limits because one often sees no animals in many transects (the same is true of many aerial sample counts), while a few transects record many sightings (Jachmann, 1991; Barnes, 2002; Hema *et al*., 2013). In addition, aerial sample counts have poor detection efficiency and return inaccurate estimates with low precision when counting scattered populations (Bouché *et al*., 2012). In both cases, indirect ground counts such as the dung technique minimizes these errors whilst maintaining a much better precision (Hema *et al***.,** 2013). There is a sufficient body of work to suggest that dropping counts provide accurate estimate of wildlife numbers (Jachmann & Bell, 1984; Johnson & Jarman, 1987; Jachmann, 1991; Whitehouse *et al.*, 2001; Barnes, 2001; Karels et al., 2004; Hema *et al.*, 2012) and a review of published literature of dropping counts of vertebrates ranging in size from lizards to elephants revealed similar estimates to those from other methods (Barnes, 2001). In particular, dung count method gives estimates that are as accurate and precise, or more precise, than aerial sample surveys (Barnes, 2001, 2002).

We observed a conspicuous gradient of relative densities of elephants between areas that exclude humans and those that sanction them across the landscape. As expected, we found elephant density estimates to be higher in fully protected areas (National Parks and Game Reserves) and lower in Lesser Protected Areas (Open Areas). High densities of elephants in NPs and GRs partly suggest the role played by hard boundaries (Sinclair *et al.*, 2002; Struhsaker et al., 2005), and arguably offer the best option available for biodiversity protection in human dominated landscapes (Bruner *et al.,* 2001; Terborgh *et al*., 2002). These results are consistent with our prediction that high relative densities of elephants are expected in FPAs due to their level of protection. However, whilst it is evident that FPAs are biodiversity cornerstones (Craigie et al., 2010; Stokes *et al*.,2010), there is a general consensus in conservation cycles for a landscape conservation approach (Rands *et al*., 2010), rather than FPAs conservation approach since unprotected areas outside FPAs that harbor relatively few large mammals and allow limited economic activities, may possess additional species that may be available in FPA in small numbers or not at all (Smart *et al*., 2005; Gardner *et al.*, 2007). For example, in a study conducted in a similar landscape found small mammals and birds to be more abundant in OAs as compared to NPs and GCAs, whereas more amphibians and birds were found in the NP relative to those obtained in OAs (Gardner *et al*., 2007). Variations not just in species richness but also numbers call for a landscape species monitoring approach (Stokes *et al*., 2010; Craigie *et al*., 2010) which calls for the need to extend large mammal survey areas beyond high density areas. Three important observations stand out from this analysis; i) the NPs had higher estimates of elephant relative densities; ii) relative densities diminished along the gradient of increasing human activity from FPAs (NPs & GRs) to LPAs (OAs); iii) and there was a consistent pattern of relative density increase/decrease to the degree of protection across the three land use or management areas designations (Table 2). However, these conclusions should be treated as preliminary due to the small sample size involved.

Here, we estimated a total of about 431 missed elephants in areas that were not covered by the aerial surveys, representing 5% of the total Ruaha-Rungwa ecosystem population. This total is relatively modest and may support the suggestion that 2014 counts for Ruaha-Rungwa ecosystem were underestimates because a few individuals may have moved out of the ecosystem during the aerial counts. Routine aerial counts for large mammals in Tanzania takes place every three years (on average) across seven major ecosystems including Katavi-Rukwa and Ruaha-Rungwa ecosystems comprising a combined total area of 45, 961 km^2 (Two NPs & Seven GRs). The neighborhoods of these two ecosystems comprise a contingent of multiple land use areas (Eight GCAs & Eight OAs) with a combined total area of about 34,196 km^2. The 2014 aerial censuses indicate that Rungwa-Ruaha ecosystem to have estimated 8,272 (±1,652 SE) compared to 20,090 (±3,282 SE) individuals, representing a drop of about 76% compared to the 2013 censuses (TAWIRI, 2014). However, with free movement of species between and among PAs, and given the minimum or no habitat variability across the landscape, there is potential for elephants to move and hide in areas where surveys are not taking place. If such results are similar elsewhere,the overall population estimates for Africa could be significantly higher. Such uncertainty in the future could be addressed by including indirect surveys of low-density areas alongside the routine censuses, with indirect counts being the most appropriate method given the cost involved. At present, Aerial census are largely undertaken in high density areas because of the high costs involved and the challenge of observer fatigue when working in areas of very low animal abundance (Whittaker *et al*., 2003).

CONCLUSIONS

Resources for wildlife conservation are scarce (Schlossberg *et al.*, 2016), yet the needs to monitor wildlife population trends are urgent because of expanding human pressures around protected areas (Hema *et al*., 2011). The concern is that the world's largest remaining biodiversity hotspots are found in developing countries which have limited resources to monitor them and especially those species that are found in low density areas. Surveying large but low-density areas in a limited resource environment requires cheap but accurate methods and dung counts have proven a useful tool to employ in these circumstances since they also provide accurate estimates. Dung counts can be applied to all savannas, bush lands and woodlands elsewhere across the continent (Hema *et al.*, 2013), and may be applied not just to PAs of modest size but also to large ecosystems where estimates of trends for all herbivores are needed (Caro, 2008). Furthermore, in areas such as the study area where poaching has been intense and animals are shy, dung counts may give an estimate of trends better than the direct ground counts (Hema *et al*., 2013). However, many wildlife managers have been skeptical about the validity of dung counts in general (Hema et al., 2013). Our results should help demonstrate that the method yield meaningful estimates if implemented properly. Furthermore, we provide further support for the growing concern that an exclusive focus of monitoring efforts on FPA network is insufficient for the successful monitoring of biodiversity (Woodwell, 2002) and reinforces the importance of an ecosystem monitoring approach in human-dominated landscapes (Evans *et al*., 2006; Gardner *et al*., 2007).

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ECOLOGY OF LESSER FLAMINGOS IN THE MOMELLA LAKES, ARUSHA NATIONAL PARK, TANZANIA

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ABSTRACT

The study was conducted to explore factors influencing food availability and habitat utilization of lesser flamingos following their frequent die-offs, population fluctuations and decline. The study was conducted in lakes Big Momella and Rishateni between November, 2013 and May, 2014 and considered flamingo numbers and flamingo related factors, namely, water quality and algal biomass. Estimates of lesser flamingo numbers were obtained using ground count census method. In-situ water testing for physical status was undertaken using a portable analyser and water samples collected for analysis (algae species composition) at University of Nairobi and Ngurdoto Defloridation Research Station (algal biomass and nutrients). It was observed that with the exception of water pH and salinity, other physico-chemical parameters (temperature, dissolved oxygen, light transparency, total nitrogen and total phosphorus) showed strong positive correlation with variations in algal biomass. Mean algal biomass varied from 4.32µg/l to 9.86µg/l and from 4.86µg/l to 10.95µg/l in lakes Big Momella and Rishateni as observed from November, 2013 and April, 2014 respectively. However, the influence of electrical conductivity, salinity and total nitrogen on algal biomass differed significantly between the two lakes ($F_{1, 13} = 34.578$, $P < .005$, $F_{1, 13} = 617.522$, $P < .005$ and $F_{1, 13} = 5.975$, $P < 0.031$ respectively). Harmful algae species such as Microcystis and Anabaenopsis were also identified in water samples from both lakes. Variations in lesser flamingo population numbers negatively correlated with algal biomass in lakes Big Momella and Rishateni ($r = -0.828$, $P < .022$, and $r = -0.792$, $P < .034$, respectively). It can be inferred that physico-chemical parameters cause shifts in algal biomass which in turn affects food availability and hence habitat utilization by lesser flamingos in the lakes. Based on the findings this study recommends further research on the sources of nutrients and identification of specific cyanotoxins that are lethal to lesser flamingos.

Keywords: Algal biomass, Arusha National Park, lesser flamingos, Momella lakes, water quality

INTRODUCTION

Lesser flamingos (*Phoenicopterus minor*) are wading water birds found in three sub-Saharan regions and other tropical regions, namely East Africa, Southern Africa, West Africa, Pakistan and North Western India (Mlingwa & Baker, 2006). Lesser flamingos are algivorous filter feeders and this unusual mode of feeding is enabled by the modification of their bill structures that allow them to pump water speedily into the filtering system for food extraction at a constant volume rate of 31.8 l/hr (Tuite, 2000; Githaiga, 2003). The majority of lesser flamingos are found in most of the East Africa Rift Valley saline lakes including the Momella lakes where they feed on blue green algae Arthospirafusiformis and occasional resort to benthic diatoms (Tuite, 2000; Mlingwa & Baker, 2006; Marttila, 2011). The current population is estimated to be 1.5 to 2.5 million birds in all 9 alkaline - saline lakes of the Great Rift Valley in East Africa (Githaiga, 2003). Lake Natron is by far the most significant breeding site for the East Africa lesser flamingo population while the Momella lakes form one among the most important feeding sites (Tuite, 2000). Lesser flamingos' distribution and movements are mainly influenced by food availability which in turn is subjective to water quality and quantity (Tuite, 2000; Githaiga, 2003). They are principally selective in their feeding habitats to the extent that any change with regards to the chemistry of the water, food quality and quantity is enough to make them shift from one saline lake to the other, a fact which makes them ecologically important as environmental bio-indicators (Tuite, 2000; Krienitz & Kotut, 2010). Morphologically lesser flamingos are pinkish/white and smaller in size weighing up to 2 kgs with lifespan of between 30 to 40 years (Marttila, 2011). They are very attractive wherever they are found in the soda lakes as they possess a dark carmine red bill, downward curved with a black tip which looks entirely black in the field, filtering mode of feeding and the colourful V-pattern shape they form during flights (Tuite, 2000; Krienitz & Kotut, 2010). Consequently, flamingo tourism is a key source of revenue and employment in Tanzania and Kenya. This benefit is likely to be affected by negative changes in flamingo numbers.

The rapid changing environment either due to uncontrolled anthropogenic activities, climate change, habitat loss or habitat fragmentation has a huge impact on ecology of many wildlife species especially those with limited habitats and narrow range of resources such as lesser flamingos (Kideghesho *et al*., 2006; Mlingwa & Baker, 2006). Frequent deaths and general decline in lesser flamingo population numbers in various East African Rift Valley soda lakes has recently triggered many research studies on lesser flamingo's ecology (Lugomela *et al*., 2006; Mlingwa & Baker, 2006; Fyumagwa *et al*., 2013). In the July- August 2004 period, for instance, about 43,850 lesser flamingo carcasses were recorded in Lake Manyara in Tanzania (TANAPA, 2005; Kihwele *et al*., 2014). Besides, unpredictable incidences of mass mortality of lesser flamingos were also reported in the Kenyan Rift valley soda lakes (Ndetei & Muhandiki, 2005). According to the findings, in 2000 an estimated number of over 30,000 birds died in Lake Bogoria in Kenya. Moreover, the highest death rates of between 15 and 50 flamingos per day were recorded in July and August, 2004, and during this period an estimated number of 1050 dead flamingos were also counted at Lake Big Momella (TANAPA, 2005). A few studies have been done to establish the causes for the lesser flamingo die-offs and their decline in various soda lakes including the Momella lakes (Lugomela *et al*., 2006; Mlingwa & Baker, 2006; Krienitz & Kotut, 2010; TAWIRI, 2012). However, information about factors influencing food availability and habitat utilization by lesser flamingos is limited. This study intended to address this problem and is based on the premise that lesser flamingo food availability, including quantity and quality are all governed by water quality parameters, which are therefore the key determinant of lesser flamingo feeding ecology. Good feeding habitat with attributes like appropriate water chemistry which enables the growth of blue green algae, diatoms, and several hours of sufficient calm waves each day for the lesser flamingos to feed are vital.

It is worthy to note that the IUCN (2018) Red List, lesser flamingos were classified as Near Threatened Species because of infrequent breeding,degradation of their specialized breeding sites and feeding habitats (Zaccara *et al.*, 2011). Other threats include the impacts of urbanization, agriculture and mining which are associated with hydrological changes, fluctuating lakes levels, water pollution, avian infections, increased predators (e.g. Marabou Stork), and illegal trade activities including harvesting of eggs and live birds (Tuite, 2000; Zaccara *et al.*, 2011). Further, algal blooms due to excess nutrients as already revealed by some studies affect not only the spatial and temporal distribution, but also quality of food for lesser flamingos (Lugomela *et al.*, 2006). Cyanobacteria are best known as the dominant species of most algal blooms that can produce a variety of toxins collectively known as cyanotoxins. Some cyanobacteria e.g. Microcystis spp. produce cyanotoxins which, when present in high concentration have the potential to kill not only the lesser flamingos, but also other animals by blocking neuronal signal transmission and inhibition of protein metabolism (Krienitz & Kotut, 2010).

Based on the above information, this study was part of the effort to establish the possible causes of the mass mortality, lesser flamingo population fluctuations and their general decline in the Momella lakes by exploring factors influencing food availability and habitat utilization. According to the Report by Tanzania National Single Species Action Plan (2010), conservation of lesser flamingo, as a flagship species, is important for sustainable management of natural resources and biodiversity, so as to sustain ecosystem functions. Besides, the presence of lesser flamingos and other species in the Momella lakes ecosystem attract many tourists and that is crucial for Tanzanian government economy as it ensures more collection of revenues. In 2015, the Tourism Sector report revealed that the tourism industry contributes about 17% of the GDP and provides direct employment to around 600,000 and indirectly to 2,000,000 people (URT, 2015). The study was therefore necessary in order to determine the likely drivers of flamingo mortality and population decline and possible management solutions.

MATERIALS AND METHODS

Study area

The study was conducted in two of the Momella lakes namely Big Momella and Rishateni that are located on the slopes of Mount Meru in Arusha National Park (Fig. 1). Other lakes that are found in proximity to the two lakes are Kusare, Elkotoito, Small Momella, Lekandiro and Tulusia. The choice was based on the fact that the two lakes are frequently affected by algal blooms and are the main feeding sites for lesser flamingo population in the ecosystem(URT, 2009; TAWIRI, 2012). The Big Momella lake is located between latitude: 3°13’22.08” S and longitude: 36°54’33.48” E and has a length of 9.5 km. Lake Rishateni is located next to Lake Big Momella between latitude: 3°13’57” S and longitude: 36°54’34” E and has a length of 3.49 km with mean and maximum water depth of 1 and 10 meters respectively (Melack, 1977; Marttila, 2011). Unlike Lake Rishateni, Lake Big Momella accommodates the largest number of lesser flamingos (Marttila, 2011). The two lake ecosystems are rich in terms of biodiversity because they attract many water birds species such as maccoa ducks, little grebes, Egyptian geese, herons, greater flamingos and mostly lesser flamingos (*Phoeniconaias minor*). Average annual rainfall in the area is about 900 mm with temperature ranging between 12 – 28 oC depending on the altitude and time of the year. Rainfall and surface runoffs are the main sources of water for the lakes (Marttila, 2011).

Data collection

Surface water samples for analysis were taken using a 1 litre water sampler on monthly basis between November, 2013 and May, 2014, of which November, December, January and February are considered as dry months with little rains and March, April and May are of heavy rains. The choice of the sampling sites was based on the locations which were heavily utilized by lesser flamingos, shoreline configuration, accessibility and safety (Githaiga, 2003). The number of sampling sites was determined based on the size of the lake and were three geo-referenced sampling sites (S1, S2 and S3) in each lake (Fig.2).

Physicochemical parameters included water pH, temperature, electrical conductivity, dissolved oxygen, salinity, light transparency, total nitrogen and total phosphorus. Except total nitrogen, total phosphorus and algal biomass determination were analysed in the lab, other parameters were determined in situ using portable calibrated electronic equipment. Water pH was determined using a portable calibrated digital Orion 4 STAR pH/ISE Meter. Electrical conductivity was determined by

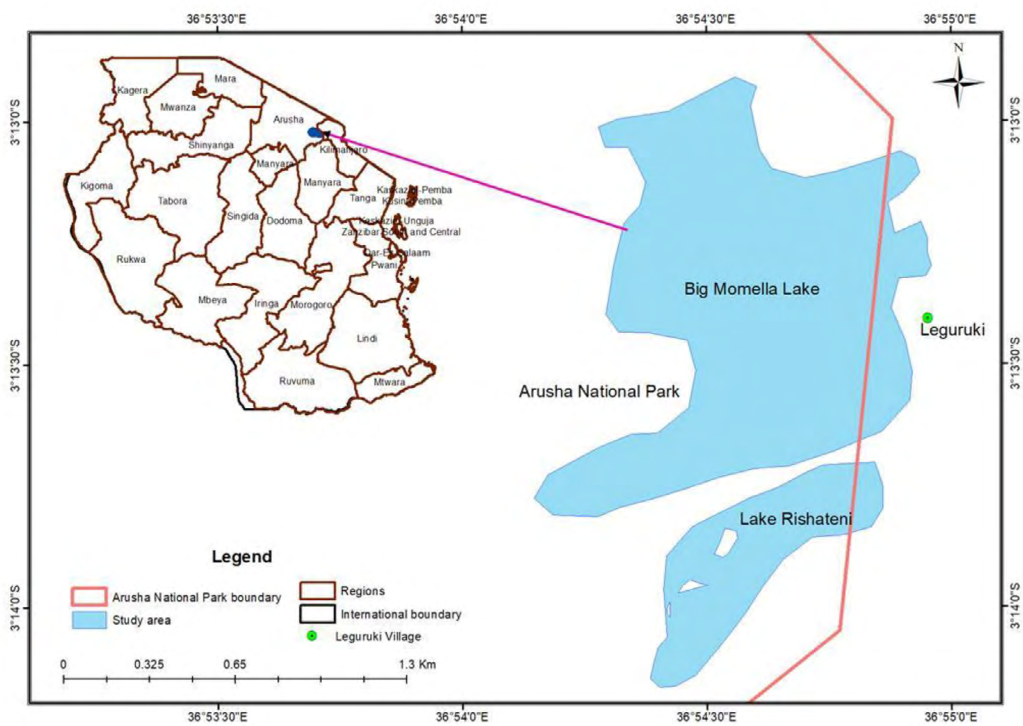

Fig. 1. Map of the study area

using a portable digital HACH-SensION5 Water Proof Conductivity Meter. Dissolved oxygen was tested using a portable calibrated digital HACH-SensION6 Dissolved Oxygen Meter, while light transparency was measured using a 20-cm diameter Secchi disc (APHA, 1998).

Total phosphorus was analysed using the Acid Persulfate Digestion Method followed by Ascorbic Acid Method. Total nitrogen was analysed in all its forms using the Nessler Method, Diazotization Method and Ion Selective Electrode (ISE) for assessment of ammonia, nitrites and nitrates respectively (APHA, 1998). Algal biomass (µg/l) was determined by measuring chlorophyll a concentration using DR 2000 spectrophotometer (APHA, 1998). Algal species identification was done using a digital microscope (LAS EZ version 1.8.0) at x100 and x400 magnification with the help of algae identification manuals(Cronberg & Annadotter, 2006).

The ground count census method was used to estimate the lesser flamingo numbers and was done monthly during the study period. The lakes were purposively divided into vantage points and there were four vantage points along the shoreline in each lake. The counting was done by standing on the vantage points during the morning hours between 9.00 to 11.300 a.m. when birds were calmly feeding with minimum movements (Githaiga, 2003). Telescope (Orion Go Scope II 70 mm) and binoculars (Orion Delux 8 x 42) were applied for easy identification and the counting of individual birds (Bennun & Nasirwa, 2000; Githaiga, 2003).

Figure 2:

RESULTS

Physical parameters

It was observed in both lakes that with the exception of water pH and salinity that remained fairly constant, other physical parameters displayed noticeable differences during the study period (Fig. 3& 4).

Nutrients

Total phosphorus

General trend in both lakes showed that concentration of phosphorus from November, 2013 to February, 2014 was relatively low compared to the rest of the months (March, April and May, 2014). In Lake Big Momella the highest and lowest concentrations of phosphorus were 2.63 mg/l and 0.08 mg/l recorded in April, 2014 and November, 2013 respectively. Unlike Lake Big Momella the highest and lowest concentrations of phosphorus in Lake Rishateni were 1.75 mg/l and 0.05 mg/l recorded in March, 2014 and in November, 2013 respectively. However, the concentration of total phosphorus in March and April, 2014 was relatively higher compared to Lake Rishateni (Fig.5).

Total nitrogen

Like phosphorus, general trend of nitrogen concentration in both lakes from November, 2013 to February, 2014 was relatively low followed by a gradual increase in January to April and a slight decrease in May with respect to Lake Big Momella (Fig.6). The lowest and highest concentrations of nitrogen were 2.9 mg/l and 38.4 mg/l recorded in November, 2013 and April, 2014. Unlike Lake Big Momella, the lowest and highest concentrations of nitrogen in Lake Rishateni were 1.9 mg/l and 9.3 mg/l recorded in November, 2013 and May, 2014 respectively. Comparatively, the concentration of nitrogen was noted to be higher in Lake Big Momella during the whole study period (Fig.6).

Algal biomass (µg/l)

There were noticeable variations in algal biomass during the study period in both lakes. In Lake Big Momella, for instance, mean algal

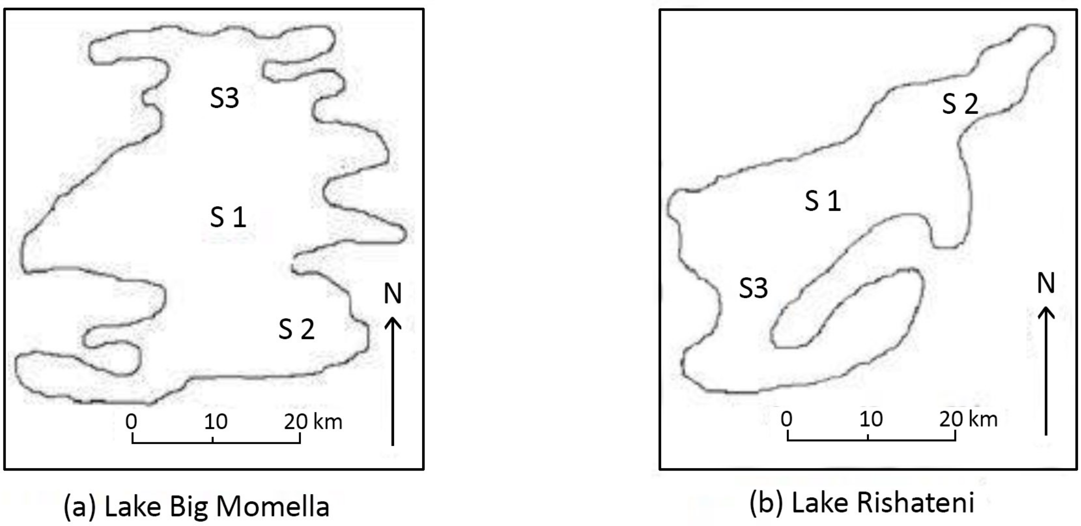

Fig. 2. Sketch maps of lakes Big Momella (a) and Rishateni (b) showing sampling sites

biomass varied from 4.32µg/l to 9.86µg/l as recorded in December, 2013 and April, 2014 respectively. In Lake Rishateni, the mean algal biomass varied from 4.86µg/l to 10.95µg/l in November, 2013 and April, 2014 respectively. The trend in mean algal biomass in both lakes was relatively the same; that is with the exception of December, 2013 there was a progressive increase up to April, 2014 and there after a decrease in May (Fig. 7).

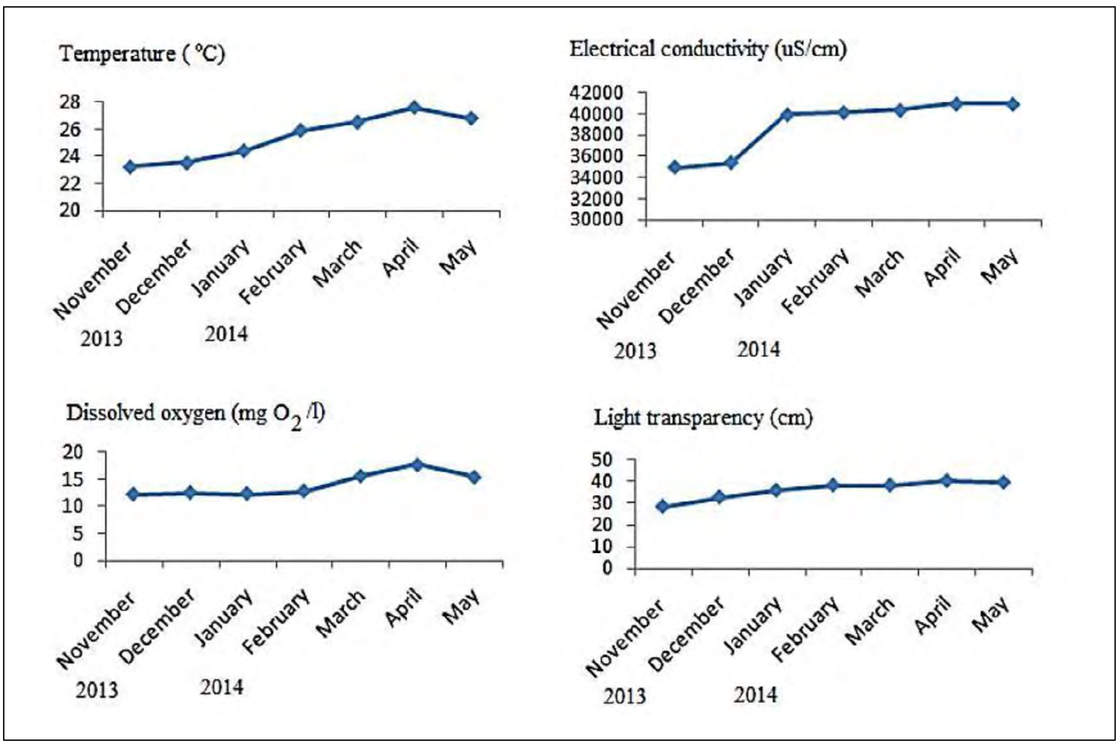

Fig. 3. Monthly changes of physical parameters in Lake Big Momella

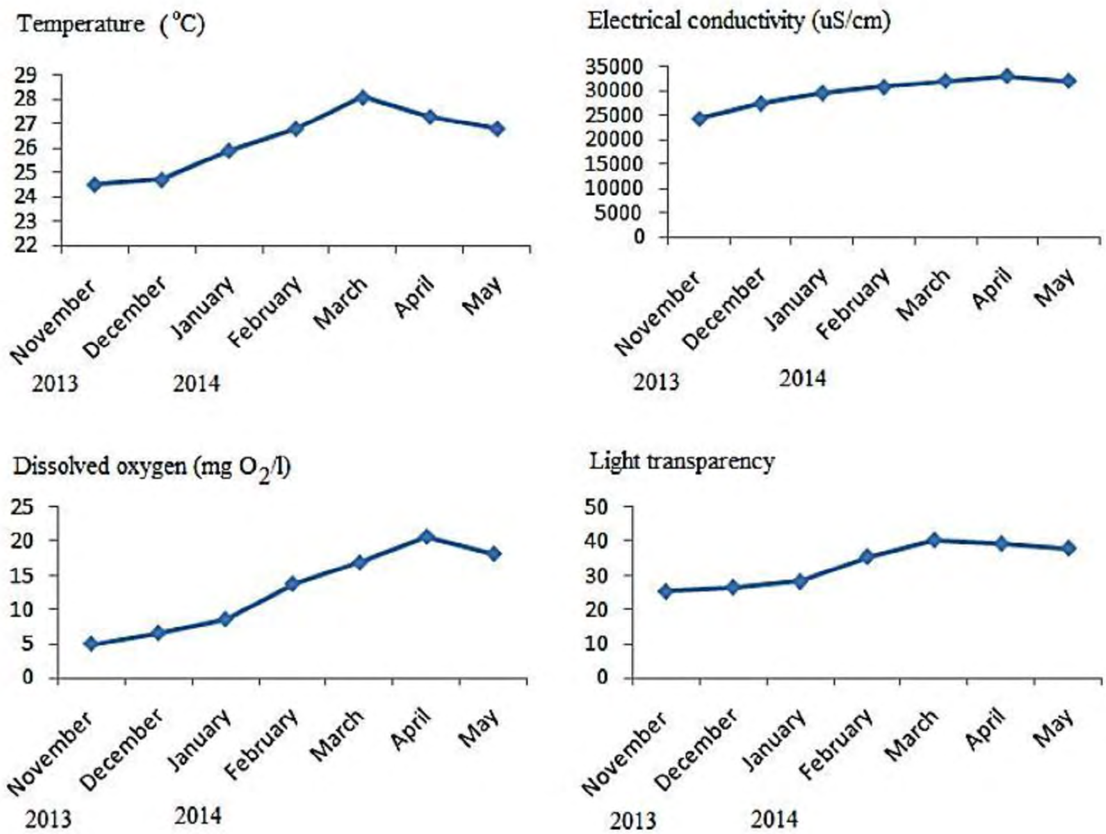

Fig. 4. Average monthly changes of physical parameters in Lake Rishateni

Influence of physico chemical parameters on algal biomass

With the exception of salinity and water pHall other parameters showed significant positive correlation with algal biomass (Table 1).

Lesser flamingo counts

The trend in lesser flamingo counts generally showed a rapid decrease in the total number of birds in both lakes during the study period. At the Lake Big Momella, the highest and the lowest numbers were 43,914 and 306 as recorded in November, 2013 and May, 2014 respectively. At Lake Rishateni the highest number was 12,495 recorded in November, 2013 and the lowest number was 0as recorded in the last three months (March, April and May, 2014). Comparatively, Lake Big Momella was found to accommodate a larger total number of lesser flamingos than Lake Rishateni in all the months during which this study was conducted (Fig.8).

Algal biomass and temporal variation in lesser flamingo counts

Pearson's r for the correlations between algal biomass and the temporal fluctuation of lesser flamingo population numbers in lakes Big Momella and Rishateni were statistically significant($r = -0.876$, $P<.05$,$r = -0.942$, $P<.05$ respectively). This indicated that there was a strong negative correlation between these two variables; that is as algal biomass was increasing lesser flamingo population numbers were decreasing in the lakes. The coefficients of determination (r^2) in lakes Big Momella and Rishateni were 0.767and 0.880 respectively indicating that 77% and 88% of the fluctuations in the number of lesser flamingos observed during the study period in the lakes could be explained by variability in algal biomass.

Spatial distribution

With regard to spatial distribution it was observed at the beginning of the study (November, 2013 to January, 2014) that lesser flamingos were widely dispersed in lakes Big Momella and Rishateni and utilized mostly the inshore and offshore areas of the lakes (Fig. 9&10).

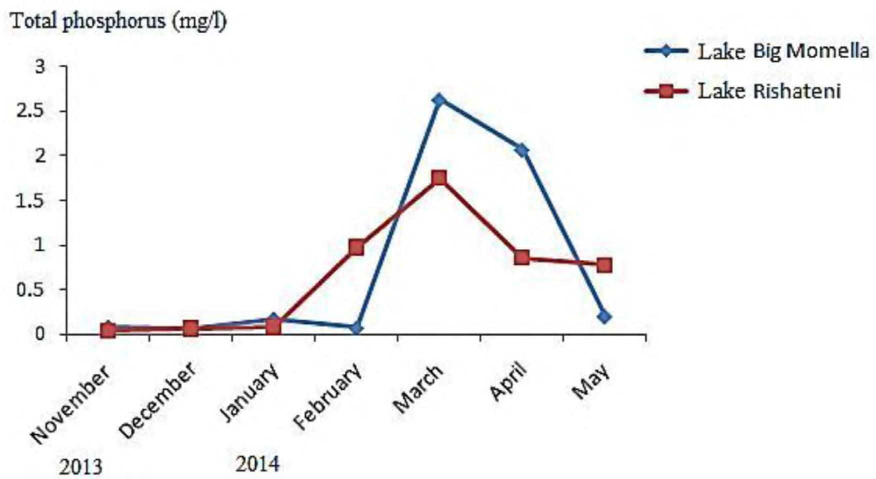

Fig. 5. Monthly changes in total phosphorus concentration in lakes Big Momella and Rishateni during the study period (November, 2013 to May, 2014).

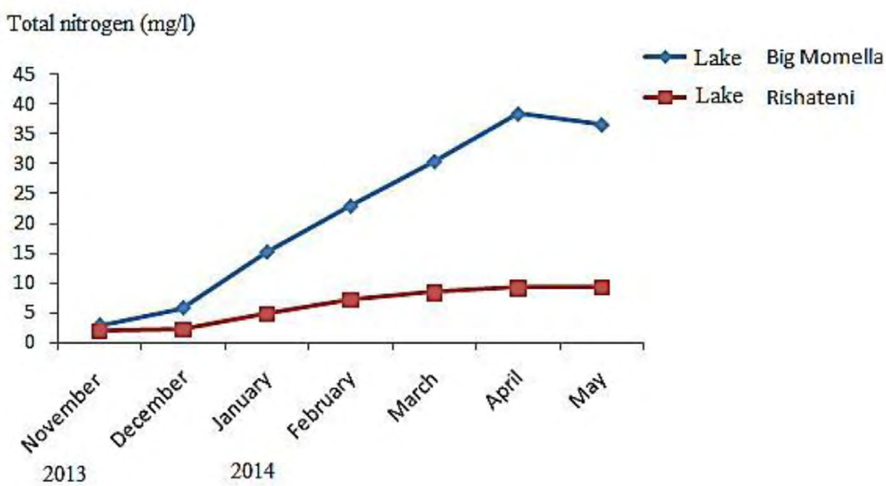

Fig. 6. Monthly changes in total nitrogen concentration in lakes Big Momella and Rishateni during the study period (November, 2013 to May, 2014).

DISCUSSION

Physicochemical parameters and shifts in algal biomass

The findings of this study revealed that there were significant differences between the physicochemical parameters as the driving factors causing not only shifts in algal biomass, but also unpredictable proliferation of algal blooms in the study lakes. Variations in algal biomass were negatively associated with temporal fluctuations in lesser flamingos that utilized the lakes for feeding during the study period. This gives a clear indication that shifts in algal biomass and proliferation of algal blooms caused by changes in physicochemical parameters greatly affect flamingo food quality

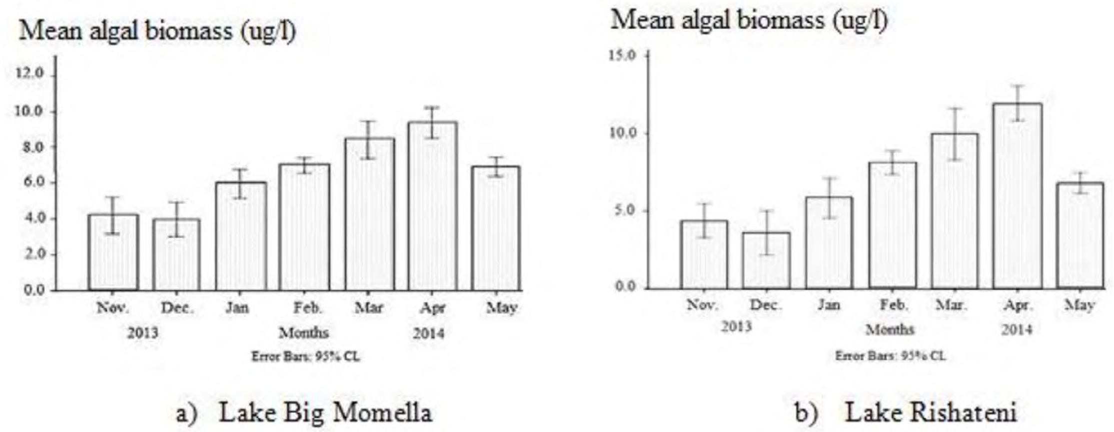

Fig. 7. Monthly changes in mean algal biomass in lakes Big Momella and Rishateni

and food availability (Tuite, 1979; Kihwele *et al.*, 2014) resulting in fluctuations of the numbers of lesser flamingos in the lakes as observed during the study period. Phosphorus and nitrogen were among the key driving factors that accelerated the increase in algal biomass and rapid growth of algal blooms especially in April, 2014. This is because nutrient enrichment particularly phosphorus

Table 1. Influence of physicochemical parameters on algal biomass

Parameters	**Lake Big Momella**		**Lake Rishateni**	
	r values	***P values***	***r values***	***P values***
Temperature (^oC)	= 0.956	< . 001	= 0.927	< . 003
E.C (µS/cm)	= 0.813	< . 026	= 0.857	< . 014
D.O (mgO_2/l)	= 0.921	< . 003	= 0.921	< . 003
Light Transparency (cm)	= 0.882	< . 009	= 0.951	< . 001
Total nitrogen (mg/l)	= 0.944	< . 001	= 0.916	< . 004
Total Phosphorus (mg/l)	= 0.803	< . 030	= 0.865	< . 012

and nitrogen as already revealed by other findings play a significant role in determining primary production and species composition in many aquatic ecosystems (Githaiga, 2003). The sources for high nutrients influxes in the lakes are yet to be identified, but could be due to uncontrolled anthropogenic activities like agriculture and livestock keeping that are practiced near the borders on the North Eastern side of Arusha National Park (Fig. 1). This implies that during heavy rains runoffs from the catchment areas can bring in nutrients from the fields and settlements (Mwaura & Moore, 1991). Moreover, it was observed during the study period that lakes Big Momella and Rishateni supported large numbers of lesser flamingos especially in November and December, 2013. Based on this context the high numbers of lesser flamingos and other water bird species could be another

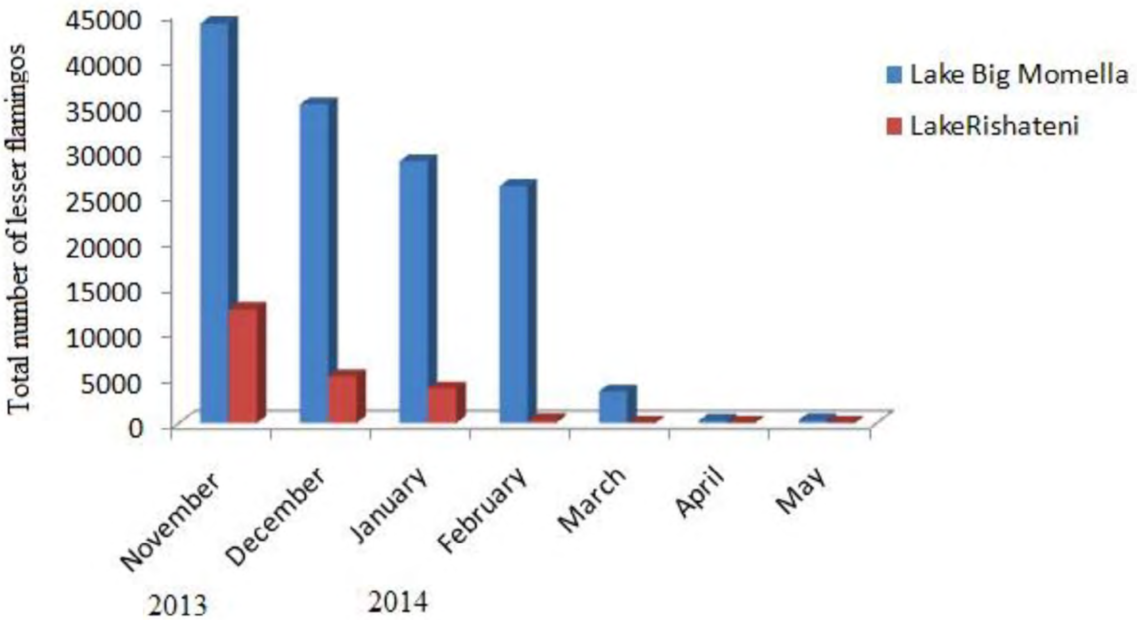

Fig.8. Temporal variations in lesser flamingos in lakes Big Momella and Rishateni during the study period (November, 2013 to May, 2014).

possible source for the high concentration of nitrogen observed that is contributed through their faecal materials (Kihwele *et al.*, 2014).

Harmful algal species

Identification of harmful algal species such Microcystis and Anabaenopsis that mixed up with the food for the lesser flamingos (*A. fusiformis*) in both lakes could be another reason for the die-offs and fluctuations in lesser flamingo population numbers. These two species gave more confirmation that there might be a problem with the quality of food for the lesser flamingos in the lakes. This is because the blue green algae in the lakes was composed of not only the common diet *A. fusiformis*, but also other algal species like the Microcystis and Anabaenopsis which have been recorded in water bodies in the Kenyan rift valley (Krienitz & Kotut, 2010) and which are known to be harmful to livestock and other aquatic organisms including lesser flamingos (Mwaura, 2004; Lugomela *et al*., 2006). The cyanobacteria have been associated with the production of harmful hepatotoxins and lipopolysacharide and endotoxins. Anabaenopsis spp. is not only too large to be ingested by the lesser flamingo, but also has the potential to congest and block filtration system of lesser flamingos as they normally occur in large and slimy colonies (Krienitz & Kotut, 2010).

Algal biomass and temporal fluctuations of lesser flamingos

The ultimate impacts of the changes in the physicochemical composition of water were manifested in the shifts of algal biomass which was associated with decrease in flamingo numbers. At the beginning of the study in November, 2013 large numbers of lesser flamingos were seen utilizing both lakes for feeding. About 43,914 and 12,495 were counted in Lake Big Momella and Lake Rishateni respectively according to the counts done in November, 2013. The presence of such large numbers indicated that for the past one or two months before the commencement of the study, the lakes had favourable conditions for the lesser flamingos including good water quality together with the presence of their common diet *A. fusiformis* and/or benthic diatoms (Ballot *et al*., 2004). Consequently, the decrease in number of lesser flamingos implied that the food was contaminated by other harmful algae species such as the identified Microcystis and Anabaenopsis and this could be one among the factors towards the die-offs, temporal fluctuations and general decline in the number of lesser flamingos inhabiting the lakes as also reflected in other studies (Vareschi, 1978; Tuite, 1979; Lugomela *et al*., 2006). This is because if *A. fusiformis* biomass falls below a certain threshold; lesser flamingos are not able to obtain enough food to meet their energy requirements and consequently, lesser flamingos can move to other saline lakes with a more favourable food base (Lugomela *et al*., 2006; Kaggwa *et al*., 2013).

Spatial distribution of lesser flamingos

Algal blooms and scum that started to appear in February, 2014 in some areas in the shores of the lakes made lesser flamingos unable to utilize the lakes which changed their distribution patterns from scattered to clusters in the lakes (Fig. 9 & 10). The presence of algal blooms and scum during the study period was characterized by discoloration in the water from their pigments and decrease in dissolved oxygen. Scum and algal blooms have various implications on lesser flamingo distribution patterns as they tend to make availability of A. fusiform is patchy in both space and time (Kihwele *et al*., 2014). Hence, the flamingo population becomes clumped at areas of high *A. fusiformis* density so that they can take advantage of exceptionally good feeding conditions and avoid the areas with blooms. Moreover, lesser flamingos tend to avoid algal bloom areas because scum and algal blooms have an effect not only on the food filtering process, but also swimming (Tuite, 1979). Therefore, the presence of scum and algal blooms that appeared in the lakes could again be one of the factors that affected not only patterns of distribution, feeding and habitat utilization but also temporal fluctuations of the lesser flamingos in the Momella lakes ecosystem.

Conclusion

It can be inferred from the findings that changes in physicochemical parameters, high nutrient levels, algal blooms and food contaminations by harmful algal species influenced the feeding behaviour and utilization patterns of lesser flamingos in Momella lakes ecosystem in Arusha National Park. It has been observed that these diverse factors do not operate independently, but in unison to bring out the undesired consequences on the feeding ecology and habitat utilization by the lesser flamingos in lakes. Variations in the physicochemical parameters greatly influenced shifts in algal composition and proliferation of algal blooms in the study lakes. High levels of nutrients particularly phosphorus and nitrogen were the main driving factors that accelerated shifts in algal biomass and the emergence of algal blooms in the lakes. The proliferation of algal blooms was a clear sign that the water is not in good quality, especially at the onset of the rain season during which nutrient flushing is highest. Algal composition was again another problem that affected the food for the lesser flamingos. This calls for more research on sources and identification of specific toxins that lethal to lesser flamingos in the lakes. It is also important to ensure proper land use in areas to the upstream of the lake ecosystems in order to prevent lake eutrophication.

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DAILY PROGRAMME
PRE-CONFERENCE EVENTS

Tuesday 03th December 2019

Time	Activity	Location/Venue	Responsible
9:00-16:00	Biodiversity survey: Birds and traditional medicinal plants of Tanzania	Twiga Conference Hall-AICC	Julius Keyyu & Organizing Committee
15:00 – 18:30	Delegates/participants arriving & registration	AICC - Conference registration desk	Organizing Committee

DAY ONE WEDNESDAY 04th DECEMBER 2019

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 - 09:00	Welcome remarks and introductory speech	Director General- TAWIRI	MC
(iv)	09:00 - 9:30	Opening Speech	Guest of Honor-Minister - MNR	MC
(v)	09:30 - 09:40	Launching ceremony		MC
		Introductory remark-Launching	Director of Research	MC
		A Word from USAID Delegate	Deputy Mission Director-USAID	MC
		A Word from NIBR Delegate	NIBR President	MC
		Launching of important TAWIRI documents	Guest of Honor-Minister - MNRT	MC
		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	Natural resource management in East Africa needs urgent rethinking	Han Olff	Dr. Maurus Msuha

DAY ONE: MORNING PARALLEL SESSION 1: SIMBA CONFERENCE HALLSUB-THEME: HUMAN-WILDLIFE INTERACTION				
S/N	**Time**	**Paper**	**Presenter**	
2	11:15-11:30	Indicators of an ecosystem under pressure: how long-term animal movement data can inform Serengeti management	Grant Hopcraft	Julius Kibebe
3	11:30-11:45	Conservation translocation of African lions Panthera leo; Implication for conflict management, translocants welfare and animal communities	Dennis Ikanda	
4	11:45-12:00	Characterizing elephant (Loxodonta africana) movement outside of protected areas in the western Serengeti	Kristen D. Snyder	
5	12:00-12:15	Re-wilding the protected areas in Tanzania: Success and challenges for the current wild animal re-introduction practices	Emmanuel Masenga	
6	12:15-12:30	Estimating population density of African leopard (Panthera pardus) and evaluating a WMA on its capacity to successfully protect wildlife through camera trap surveys in Tanzania's greater Ruaha ecosystem	Charlotte Searle	
	13:00– 14:00	**LUNCH**	**All**	**OC/MC**

DAY ONE: AFTERNOON PLENARY SESSION 2: KEYNOTE PAPER PRESENTATION No. 2- SIMBA CONFERENCE HALL				
7	14:00-14:20	Comparison of direct and indirect methods for estimating elephant abundance in the miombo woodlands in south-western Tanzania	Alex L. Lobora	Anna Estes
8	14:21-14:40	Large carnivore status & distribution in the Ruaha-Rungwa landscape: implications for conservation in human-impacted areas and for trophy hunting	Paolo Strampelli	
9	14:40-15:00	The effect of migratory wildebeest on tourism demand in the Serengeti	Freja Larsen	
10	15:01-15-20	Chimpanzee (P. t. schweinfurthii) food species in a human-impacted area, the Masito-Ugalla Ecosystem, Tanzania	Simula Maijo	
11	15:41-16:0	Using the Mitochondrial DNA (mtDNA) control region to infer genetic diversity of the Eastern Black rhinoceros (Diceros bicornis michaeli) in Tanzania.	Ronald V. K. Mellya	
	16:00-16:30	**Health break**		
12	16:31-17:30	Round Table Discussion 1: Wildlife Collaring and Database Management strategy in Tanzania	Emmanuel Masenga	Michael Veldhuis
	19:00-21:00	**EVENING SCIENTIFIC GATHERING FOR TAWIRI AWARDS: AICC NYASA HALL**		
END OF DAY ONE				

DAY ONE: MORNING PARALLEL SESSION 2: TAUSI CONFERENCE HALL SUB-THEME: HUMAN-WILDLIFE INTERACTION				
S/N	**Time**	**Event/Paper**	**Presenter**	**Chairperson**
13	11:20-11:40	Foraging ecology of White-backed vultures in southern Tanzania	Corinne Kendall	Devolent Mtui
14	11:40-12:00	Spatial-temporal movement and home range variations of African elephants in South-western Serengeti Ecosystema	Emmanuel Masenga	
15	12:01-12:20	Increasing tolerance leads to safer lion landscapes	Jannson Ingela	
16	12:21-12:40	Efficacy of spotlights and thermal cameras to detect lions Panthera leo and spotted hyenas Crocuta crocuta	Stanslaus B. Mwampeta	
17	12:41-13:00	Abundance and distribution of amphibians and reptiles in Mkomazi National Park, Tanzania	Glory Summay	
	13:00 -14:00	**LUNCH**		**OC/MC**

18	14:00-14:20	Unhabituated chimpanzees (Pan troglodytes) in the Village Forest Reserves north of Gombe National Park, Tanzania	Deus C. Mjungu	Jafari Kideghesho
19	14:21-14:40	Preliminary assessment of cow – calf structure of elephant population in Mikumi National Park, Tanzania	Deusdedith Bwenge Fidelis	
20	14:40-15:00	Standardized mammal monitoring in African protected areas: case studies from Bwindi and Udzungwa Mountains National Park	Emanuel H. Martin	
21	15:01-15-20	Effects of prescribed burning on the abundance and diversity of rodents in Serengeti National Park	A.M. Manyonyi	

22	15-21-15:40	Addressing Poisoning in Southern Tanzania	Claire Bracebridge	
23	15:41-16:00	Patterns of bird bushmeat hunting and trade and the effect on source population in the Swagaswaga-Mkungunero ecosystem	Shadia Kilwanila	
	16:00-16:30	**HEALTH BREAK**		
24	16:31-17:30	**Round table discussions- Simba and Oldonyo Lengai Halls**		
END OF DAY ONE				
	18:30-21:00	**EVENING SCIENTIFIC GATHERING FOR TAWIRI AWARDS : AICC NYASA HALL**		

DAY ONE: MORNING PARALLEL SESSION 3: OLDONYOLENGAI CONFERENCE HALL
SUB-THEME: WILDLIFE ECOLOGY AND ECOLOGICAL INTERACTIONS

S/N	Time	Paper	Presenter	Chairperson
26	11:20-11:40	Wildlife population trends as indicators of protected area effectiveness in northern Tanzania	*Christian Kiffner*	Flora Magige
27	11:40-12:00	Status and vulnerability of wildlife road accidents in the Serengeti Ecosystem, Tanzania	*Richard D. Lyamuya*	
28	12:01-12:20	Ecology of Lesser Flamingos (Phoenicopterus minor) in the Momella Lakes, Arusha National Park – Tanzania	Deogratias Lihepanyama	
27	12:21-12:40	Rodents feeding preference and plant nutrient dynamics in the Livingstone mountains ecosystem	*Philipo Jacob Mtweve*	
28	12:41-13:00	Tree biomass, carbon stock characteristic on diversity of ground beetles in the Udzungwa Scarp Nature Reserve, a Tanzanian Afromontane tropical forest	Anna Mwambala	
	13:00 - 16.30	**LUNCH**		**OC/MC**
29	14:00-14:20	Assessment of morphology of bats in Eastern, Tanzania	Mathayo Cralency	Emmanuel Masenga

30	14:21-14:40	Nutrient re-distribution from termite mounds in a Miombo woodland, Tanzania	Gabriel Mayengo	
31		A Chimpanzee (Pan troglodytes) census in Mahale Mountains National Park		
32		Leaf traits mediate changes in invertebrate herbivory along broad environmental gradients on Mt. Kilimanjaro, Tanzania		
33		Baboon reproductive-differences in a habitat mosaic at Gombe		
34		Population distribution, threats and conservation awareness of African clawless otter in Mtera Dam ecosystem, Tanzania		
	16:00-16:30	**HEALTH BREAK**		
35	16:31-17:30	Round table discussions 2: An integrated landscape management in Tanzania An Approach for sustainability of land-based resource	Stephen Nindi	Sara Cleaveland
END OF DAY ONE				
19:00-21:00: EVENING SCIENTIFIC GATHERING FOR TAWIRI AWARDS : AICC NYASA HALL				

DAY TWO: THURSDAY 05th DECEMBER 2019

DAY TWO: MORNING PLENARY SESSION- KEY NOTE PAPER PRESENTATION No. 2 SIMBA CONFERENCE HALL				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
36	8:30-9:10	The future of conservation: lessons from the past and the need for rewinding of ecosystems	Prof. Kideghesho	Kristen Denninger Snyder
DAY TWO: MORNING PARALLEL SESSION 4: SIMBA CONFERENCE HALL SUB-THEME: HUMAN WILDLIFE INTERACTIONS AND LAND USES				
36	9:20-9:40	Household economic conditions and bushmeat consumption: A longitudinal analysis of communities in Western Serengeti, Tanzania	Dennis Rentsch	Joseph Ogutu
37	9:41-10:00	Agricultural expansion around the Serengeti-Mara ecosystem from 1984 to 2018	Anna B. Estes	
38	10:01-10:20	How reliable are population estimates for setting annual harvesting quota?	Emmanuel H. Martin	
39	10:21-10:40	Wire livestock enclosures help reduce human-carnivore conflict	A. Graua	
	10:40 –11:00	**HEALTH BREAK**		
40	11:00-11:15	Tracking animal movements using biomarkers in tail hairs: establishing relocations of cattle in the serengeti ecosystem from a sulphur isoscape	Zabibu Kabalik	Fortunata Msoffe
41	11:21-11:40	Assessment of illegal bushmeat activities using high resolution melting analysis in Tarime District, Tanzania	Kilwanila, Ibrahim Shadia	
42	11:41-12:00	Molecular wildlife forensics in Tanzania: potential of high resolution melting analysis (HRMA) in bushmeat surveillance and identification	Mutayoba B.M	
43	11:45-12:00	The human demography and ecology of snakebites in Tanzania: the first detailed assessment of this terrible and neglected challenge	Tito J. Lanoy	
44	12:01-12:20	The Importance of Bushmeat in Household income as a function of Distance from Protected Areas in the Western Serengeti Ecosystem	Flora Felix Manyama	
45	12:21-12:40	The Role of Community Involvement for Improved Human-Elephant Coexistence in Tanzania	Alex Chang'a	

46	12:41-13:00	Influence of human activities and forest strata on the abundance of Iringa Red Colobus Monkey in the Magombera Forest Reserve	*Davide Valli*	
13:00 - 14:00		**LUNCH**		
47	14:00-14:15	Testing low cost solutions to mitigate human –wildlife conflict: a success story from west Kilimanjaro, Tanzania	Anthony Collins et al	Ezekiel Dembe
48	14:15-14:30	Assessment of human disturbances on flight distance in birds at Morogoro municipal and surrounding areas, Tanzania	Chulla Jastin Gaitan	
49	14:30-14:45	Land Cover and Landscape Changes in the Kwakuchinja Wildlife Corridor Adjacent to the main road	Emanuel H. Martin	
50	15:01–15:20	Threats to the southwestern Serengeti Habitats: Woody Encroachment and Land Use Changes	Ayoub M. Asenga	
51	15:21 -15:40	Research on the impact of ecological weed (invasive) A. zanzibarica on indigenous plants species richness, diversity, composition and its possible effective control measures in Saadani National Park	Wilson Maanga	
52	15:41-16:00	Use of Current Remote Sensing Methods for Biodiversity Monitoring and Conservation of Mount Kilimanjaro NP Ecosystems	Fortunata Msoffe	
	15:30-16:00	**Poster Presentation-Display area**		
	16:30-17:30	**HEALTH BREAK**		
53	16-30-16:45	Movement patterns, and habitat use of eland (Taurotragus oryx) in a changing landscape	Majaliwa M. Masolele	Robert Fyumagwa
54	16:45-17:00	Wildlife assessment in Mikumi – Wamimbiki wildlife corridor	*Zawadi Mahinda*	
END OF DAY TWO				
END OF DAY TWO				

DAY TWO: MORNING PARALLEL SESSION 5: TAUSI CONFERENCE HALL SUB-THEME: DISEASES AND ECOSYSTEM HEALTH				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
56	9:20-9:40	Systematic Domestic Dog Vaccination Results in Significant Declines in Rabies Exposures and Human Rabies Deaths	*Anna Czupryna*	Julius Keyyu
57	9:41-10:00	Impact of genital ulcerations caused by Treponema pallidum on the mating behaviour of female olive baboons (Papio anubis) at Lake Manyara National Park.	*Filipa M.D. Paciência*	
63	10:01-10:20	Assessment of Nature, extent and trend of giraffe skin disease in Tarangire-Manyara Ecosystems	*Kiula Faraja*	
64	10:21-10:40	Anthrax Outbreak in Wildlife within Burunge Wildlife Management Area and Tarangire National Park, Northern Tanzania: Participatory Control and Prevention	Chuma, I. S	
65	11:00-11:20	Carnivore parvovirus ecology in the Serengeti ecosystem: vaccine strains circulating and new host species identified	*Sara Cleaveland*	
66	11:21-11:40	Tick species diversity and spatio-temporal distribution in Mkomazi Black rhinoceros sanctuary, Mkomazi National Park	*Emmanuel Macha*	
67	11:00-11:20	Conservation challenges of controlling parasites in small protected areas: a case of Rubondo island and Saanane island National Parks, Lake Victoria, Tanzania	*Robert Fyumagwa*	Benezeth Mutayoba
68	11:45-12:00	Modified netting technique for capturing gazelles in Serengeti, Ngorongoro and Loliondo, Tanzania	Mdetele. D	
69	12:21-12:40	Understanding the population demographics and threats, including Giraffe Skin Disease, facing giraffe in Southern Tanzania	*Jessica Manzak*	
70	12:41-13:00	Livestock mobility in northern Tanzania: implications to domestic and wildlife disease spread	*Divine Ekwem*	
	13:00-14:00	**LUNCH**		

71	14:21-14:40	Wild Tanzanian Non-human Primates Have Antibodies Reactive With a Wide Range of Virus Antigens	*Idrissa S. Chuma*	Teresa Sylvina
72	14:41-15:00	Using low coverage whole genome sequencing to inform conservation management decisions	*Barbara K. Mable*	
73	15:01–15:20	Tsetse and trypanosomiasis in the grazing lands at villages-wildlife management area interface in Meatu District	*Deusdedit Malulu*	
74	15:21 -15:40	Canine Distemper Virus Outbreak in one of the reintroduced African Wild Dogs (Lycaon pictus) pack in the Serengeti National Park: Results from Serological and Molecular Diagnostic Analyses	*Eblate Mjingo*	
	16:01-16:30	**Poster Presentation-Display area**		
	16:30-17:00	**HEALTH BREAK**		
75	Time	Round table discussion 3: Wildlife Census	Edward Kohi	David Moyer Chairperson
END OF DAY TWO				

DAY TWO: MORNING PARALLEL SESSION 6: OLDONYOLENGAI CONFERENCE HALL SUB-THEME: BEEKEEPING, BEE ECOLOGY AND API-TOURISM				
75	9:20-9:40	Antibacterial activity of Kibaha honey bees propolis against bacteria eschericha coli	Thomas A. Morrison *et al*	Shedrack Kamenya
76	9:41-10:00	Collecting bees on Mt Meru in Tanzania and the discovery of a new cleptoparasitic species of lasioglossum (hymenoptera: apoidea: halictidae)	Titus Lanoy *et al*	
77	10:01-10:20	Greater Honeyguides (Indicator indicator) Guide Humans to animals other than bees	Alfan Rija *et al*	
78	10:21-10:40	Bee-Pollinator Monitoring Project, Tanzania	Houssein S. Kimaro *et al*	
	10:40– 11:00	**HEALTH BREAK**		

DAY TWO: MORNING PARALLEL SESSION 6: OLDONYOLENGAI CONFERENCE HALL SUB-THEME: NATURAL RESOURCES GOVERNANCE AND INFRASTRUCTURE DEVELOPMENT				
79	11:00-11:20	In search of New Modes of Governance: The Potential of Conservation Incentive Payment Policies to Promote Human-Wildlife Coexistence	Adam Pekor	Iddi Mfunda
80	11:21-11:40	The paradox of biodiversity monitoring and land use change: challenges and opportunities to inform management using open biodiversity data from GBIF in Tanzania	W. Edwin Harris	
81	11:41-12:00	Contribution Of Community Forest Conservation Efforts At Loliondo Forests, Arusha Region, Tanzania	Benson Petro Mhagama	
82	11:45-12:00	Policy Process, Institutional Framework and Outcomes of Wildlife Management Areas in Serengeti and Meatu Districts, Tanzania	Babili, I.H	
83	12:01-12:20	Communicating science for effective biodiversity conservation – With examples from NGO-GOT collaborations	Sarah J. Markes	
84	12:21-12:40	Spatio-temporal changes in wildlife habitat quality in the Greater Serengeti Ecosystem, based on InVEST Model	Hamza Kija	
85	12:41-13:00	Compliance of mining companies on regulatory framework in Tanzania: evidence from community perspectives in Kahama	Willy Maliganya	
86	13:00-13:20	Kihansi spray toad population in captive breeding facility	Person Kalenga	
	13:00 - 14:00	**LUNCH**		
DAY TWO: AFTERNOON PARALLEL SESSION 6: OLDONYOLENGAI CONFERENCE HALL SUB-THEME: HYDROLOGY AND WETLAND RESOURCE CONSERVATION				
89	14:00-14:20	The effect of climate and land-use change on river discharge within the Greater Serengeti-Mara Ecosystem	E.S. Kihwele	Halima Kiwango
90	14:21-14:40	Limnology and fisheries resources in lake Babati and Lake Burunge - Tanzania	Jackson H. Katonge	
91	15:01–15:20	Assessment of diversity of aquatic macro-invertebrates in Morogoro River	Theodora Venance Shirima	
92	15:21 -15:40	Assessment of macro invertebrates distribution and diversity in Kizinga River, Dar es Salaam Tanzania.	Jackson H. Katonge	
93	15:41-16:00	Impact of land use changes on the health of lake Babati and lake Burunge, northern Tanzania	Amar Shanghavi	
	16:01-16:30	**Poster Presentation-Display area**		
	16:30-17:00	**HEALTH BREAK**		

DAY TWO: POSTER PRESENTATIONS: 05TH DECEMBER 2019

Chairperson: Jerome Kimaro

TIME: 15:40-16:30

S/N	Title	Presenter	Sub-theme
94	Influence of rainfall and diet on rodent natural population increase: a case study of Rombo District in northern Tanzania	Musa Ashraf	wildlife ecology and ecological interactions
95	Protecting dry forests and woodlands for wildlife conservation in Tanzania	John. R. Mbwambo	vegetation ecology and ethnobotany
96	Nexus Between Maasai's Indigenous Architecture and Sustainable Tourism Development in Ngorongoro Conservation Area	Godfrey Ayubu	Human Wildlife interactions and Land-uses
97	Invasive Prosopis juliflora reduces density and species composition of co-occurring woody plants in the Northern Tanzania rangelands	Mecklina Michael	Wildlife habitat, rangelands and invasive species
98	Ecosystem Services: Social, Cultural and Economic Values of Elephants for Community's Livelihoods in the Serengeti	Janemary Ntalwila	Human Wildlife interactions and Land-uses
99	Perception of local communities towards elephant conservation in Serengeti ecosystem	Angela Mwakatobe	Human Wildlife interactions and Land-uses
100	Seasonal variation of group sizes of wild and domestic herbivores in relation to environmental and anthropogenic factors	Cecilia Leweri	Human Wildlife interactions and Land uses
101	Local perceptions, management and desirability of invasive plants species in rangelands ecosystems: Experiences from the Ngorongoro Conservation Area	Jerome Kimaro	Wildlife habitat, rangelands and invasive species
102	Valuation of Natural Resources: Can Choice experimental Method be Sustained in Tanzania?	Odass Bilame	Natural Resource Governance and Infrastructure development
103	Patterns of Resource Use Among the Mixed Subsistence-Wage Economies in Villages near Udzungwa Mountains NP: Implications for Community Design and Conservation	Kambi Mohamed	Natural Resource Governance and Infrastructure development
104	Temperature and resource diversity predict the diversity of Phytophagous beetles along elevation and land use gradient on Mt. Kilimanjaro.	Kambi Mohamed Henry K. Njovu	Climate change and wildlife conservation

105	Influence of habitat characteristics on seed predation by animals in SUA fields, Morogoro	Kanael, Joseph M.	vegetation ecology and ethnobotany
106	Efficacy of land use designation in protecting habitat in the miombo woodlands: insights from Tanzania	Alex L. Lobora	Wildlife habitat, rangelands and invasive species
107	Crows: friend or foe for the environment?	Orit Baruch	wildlife ecology and ecological interactions
108	Synergies of natural and cultural capital in the ngorongoro	Fildecastor Kimario	wildlife ecology and ecological interactions
109	Potential distribution of the invasive plant Parthenium hysterophorus inside and outside the Arusha National Park in Tanzania	Fredrick Ojija	Wildlife habitat, rangelands and invasive species
END OF DAY TWO			

DAY THREE - 06TH DECEMBER 2019				
DAY THREE: MORNING PLENARY SESSION- KEY NOTE PAPER PRESENTATION No. 3 SIMBA CONFERENCE HALL				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
110	8:30-9:10	A call for Integrative collaboration and governance of natural resources: An answer for sustainable biodiversity conservation in western Tanzania	Shadrack M. Kamenya	Han Olff
DAY THREE: MORNING PARALLEL SESSION 7: SIMBA CONFERENCE HALL SUB-THEME: CLIMATE CHANGE AND WILDLIFE CONSERVATION				
S/N	**Time**	**Event/Paper**	**Presenter**	**Chairperson**
111	9:20-9:40	Modelling trends and variation in weather variables using Univariate and Multivariate State Space Models	Joseph O. Ogutu	Stephen Nindi
112	9:41-10:00	Quantifying water requirements of African ungulates through a combination of functional traits	E.S. Kihwele	
113	10:01-10:20	Large herbivore assemblages in a changing climate: incorporating water dependence and thermoregulation	M.Veldhuis	
114	10:21-10:40	Modelling spatio-temporal variation in rainfall using a hierarchical Bayesian regression model	M.Sabyasachi	

SUB-THEME:- WILDLIFE HABITAT, RANGELANDS AND INVASIVE SPECIES				
115	11:00-11:20	IAS management can facilitate secondary invasions: applying lessons learnt to the Ngorongoro Conservation Area, Tanzania	E.F. Strange	Grant Hopcraft
116	1 1 : 2 1 - 11:40	Using MODIS Yearly Land Cover Data to Study Vegetation Changes in Mkomazi National Park 2001 to 2013	Emanuel H. Martin	
117	11:41-11:45	Estimating the invasion success of Siam weed (Chromolaena odorata) in the Western Serengeti, Tanzania	Rudolf F. Mremi	
118	1 1 : 4 5 - 12:00	Assessing management and threats of invasive plant Parthenium hysterophorus on biodiversity conservation in Tanzania	Fredrick Ojija	
119	12:01-12:20	Effects of the abundance of Parthenium hysterophorus on the composition and diversity of other herbaceous plant species in Simanjiro rangeland, Tanzania	Leticia J. Musese	
120	12:21-12:40	Invasion of Lantana camara in the Eastern Usambara Mountains, Tanzania: Local communities' perceptions on spread, Socio-economic impacts and management responses	Gasto Vicent Mush	
121	12:41-13:00	Community monitoring of grazing lands using distance sampling and vegetation plots by Maasai communities around Mt. Meru	Kone Supuk	
	13:00-14:00	**LUNCH**		
122	14:00-14:20	Effect of agro-pastoralism on herbaceous plants conservation in western Serengeti	*Kavana, P*	Silvia Ceppi
123	14:21-14:40	Potential of Wazo Hill Quarry in Stocking Carbon for Mitigating Global Climate Change	*Mtoka, S*	
124	14:41-15:00	Challenges and Opportunities for REDD+ in Pemba	*Monique B.Mulder*	
	15:01-15:40	Updates from Directorate of research	*Director of Research*	Dr. Keyyu
	15:41-16:00	Conference resolutions	All Participants	Moderator
	15:41-16:10	**HEALTH BREAK**		
	13:00-14:00	**CLOSING REMARKS- SIMBA CONFERENCE HALL**		

END OF DAY THREE – END OF THE 12TH TAWIRI SCIENTIFIC CONFERENCE
THANK YOU ALL FOR MAKING THIS EVENT ONE OF THE SUCCESS CONFERENCES

DAY THREE: MORNING PARALLEL SESSION 8: TAUSI CONFERENCE HALL SUB-THEME: VEGETATION ECOLOGY AND ETHNOBOTANY				
S/N	Time	Event/Paper	Presenter	Chairperson
125	9:21-9:40	Opuntia spp reduces the effective habitat for herbivores in Serengeti national park	*Loishooki A G*	Evaline Munisi
126	9:41-10:00	Ethnoveterinary uses of medicinal plants by selected ethnic groups in Northern Tanzania	*Thobias O. Tomeka*	
127	10:01-10:20	Woody encroachment extent and its associated impacts on plant and herbivore species occurrence in Maswa Game Reserve, Tanzania	*Houssein S. Kimaro*	
128	10:21-10:40	Conservation of Urban Forest in Tanzania: Community Attitudes towards Njiro Forest, Arusha	*G. P. Massawe*	
	10:40 – 11:00	**HEALTH BREAK**		
SUB-THEME: MIXED SUB THEMES				
129	11:00-11:20	Savannah restoration: improving ecosystem resilience following cessation of human activities	Yustina A. Kiwango	G. Meng'ataki
130	11:21-11:40	Assessment of economic viability and conservation contribution of trophy hunting in Tanzania	Abraham Mulokoz*ial*	
131	11:41-12:00	Ethnobotanical knowledge and the threat factors for Aloe species in Tanzania	*Siri Abihudi*	
132	11:45-12:00	Invasive Prosopis juliflora reduces density and species composition of co-occurring woody plants in the Northern Tanzania rangelands	*Mecklina Michael*	
133	12:01-12:20	Efficacy of motorcycle in illegal bushmeat transportation to black market in western Serengeti Tanzania	*Julius Nyahongo*	
134	12:21-12:40	Attitude and perception of tourists towards wildlife-based tourism in the Northern tourist circuit of Tanzania	*Prisca N. Kahangwa*	
135	12:41-13:00	Understanding patterns of crop damage by the African elephant	*Kwaslema Malle Hariohay*	
136	13:00-13:20	Business model structure for beekeeping commercialization in Tanzania	*Nicholaus B.Tutuba*	
	13:00-14:00	**LUNCH**		
137	14:01-14:20	Coconut crabs in Tanzania: Threats and conservation solutions	*Tim Caro*	Sascha Knauf
138	14:21 – 14:40	Rainfall, Fire and Large-Mammals Induced Drivers of Woody Plant Encroachment in Maswa, Tanzania	*Houssein S. Kimaro*	
139	14:41-15:00	Patterns of Resource Use Among the Mixed Subsistence-Wage Economies in Villages near Udzungwa Mountains National Park: Implications for Community Design and Conservation	*L.J. Gorenflo*	

	15:01-15:40	Updates from Directorate of research-Simba Hall	*Dr. Keyyu-Director of Research*	
	15:41-16:00	Conference resolutions	*All Participants*	Moderator
	16:00-16:20	**HEALTH BREAK**		
	16:21-17:00	**CLOSING REMARKS- SIMBA CONFERENCE HALL**		
END OF DAY THREE – END OF THE 12TH TAWIRI SCIENTIFIC CONFERENCE THANK YOU ALL FOR MAKING THIS EVENT ONE OF THE SUCCESS CONFERENCES				

DAY THREE: MORNING PARALLEL SESSION 9: OLDONYOLENGAI CONFERENCEHALL WORKSHOP : EXECUTION OF THE CHIMPANZEE HEALTH INITIATIVE AT MAHALE MOUNTAINS NATIONAL PARK (CHIMMP)				
S/N	Time	Event/Paper	Presenter	Chairperson
140	9:21-10:40	Execution of the Chimpanzee Health Initiative at Mahale Mountains National Park (CHIMMP): a grass roots strategy to impact chimpanzee conservation at Mahale	Bush-To-Base Solutions, Inc. in collaboration with the PMO One Health Coordination Desk	Teresa J. Sylvina
	10:40 – 11:00	**HEALTH BREAK**		
Continuation of the Workshop				
141	11:00-13:00	Execution of the Chimpanzee Health Initiative at Mahale Mountains National Park (CHIMMP): a grass roots strategy to impact chimpanzee conservation at Mahale	Yustina A. Kiwango	Teresa J. Sylvina
		LUNCH		
		Round table discussion 5		
		Updates from Director of research	**Director of Research**	**Dr. Keyyu**
		Conference resolutions		
		HEALTH BREAK	**All Participants**	**Moderator**
		CLOSING REMARKS- SIMBA CONFERENCE HALL		
END OF DAY THREE – END OF THE 12TH TAWIRI SCIENTIFIC CONFERENCE THANK YOU ALL FOR MAKING THIS EVENT ONE OF THE SUCCESS CONFERENCES				

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