PROCEEDINGS OF THE 13TH TAWIRI SCIENTIFIC CONFERENCE

"Wildlife Research for Enhancing Biodiversity Conservation and Livelihood Improvement"

December 6-8, 2021
Arusha International Conference Centre,
ARUSHA , TANZANIA

TAWIRI
Tanzania Wildlife Research Institute

TANZANIA WILDLIFE RESEARCH INSTITUTE

(TAWIRI)

PROCEEDINGS OF THE THIRTEENTH TAWIRI SCIENTIFIC CONFERENCE

December 6 - 8, 2021,

ARUSHA INTERNATIONAL CONFERENCE CENTRE,

TANZANIA

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Conference Theme

“Wildlife Research for Enhancing Biodiversity Conservation and Livelihood Improvement”

MESSAGE FROM THE ORGANIZING COMMITTEE

It has been a routine activity for the Tanzania Wildlife Research Institute (TAWIRI) to organize a scientific conference every two years. TAWIRI Scientific Conference is a forum that congregates scientists from all over the world in order to share wildlife information for sustainable conservation of natural resources. This year's meeting marks the 13th scientific conference under the theme "Wildlife Research for Enhanced Biodiversity Conservation and Livelihood Improvement". The theme aims to address efforts towards sustainable wildlife conservation while promoting livelihood improvement. The conference gathers a wide range of scientists, policymakers, conservationists, NGOs, 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 conference encompassed three broad keynote speeches that gave a guide to making sure all matters discussed were focused on the theme provided. Moreover, oral and poster presentations, symposiums, workshops, and round table discussions were conducted. It is our expectation that the presentations will address different conservation challenges and that the proposed solutions will contribute to the conservation of biodiversity and the improvement of local livelihoods.
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On behalf of the management and staff of TAWIRI, the organizing committee of the 13th TAWIRI Scientific Conference is honored and pleased to invite all scientists, conservationists, management authorities, government officials, and representatives of NGOs and civil society organizations to participate in this biannual TAWIRI conference, KARIBUNI SANA.

Organizing Committee Members

Alex Lobora	Chairperson
Hillary Mushi	Vice Chairperson
Janemary Ntalwila	Secretary
Cecilia Leweri	Member
Mwita Machoke	Member
Edward Kohi	Member
Daniel Wanna	Member
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Jerome Kimaro	Member
Stephen Nindi	Member
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Anna Mchani	Member

SPEECH OF THE DIRECTOR GENERAL AT THE OFFICIAL OPENING OF THE 13TH TAWIRI SCIENTIFIC CONFERENCE HELD AT THE ARUSHA INTERNATIONAL CONFERENCE CENTRE, ARUSHA, DECEMBER 6, 2021

First and foremost, I thank God for making this day possible, and I want to take this opportunity to thank you, **Honorable Minister in person**, for dedicating your time to come an=d officiate the opening of the Thirteenth TAWIRI Biennial Scientific Conference, despite your very tight schedules.

I would also like to thank **Hon. John Vianney Mongella**, the Arusha Regional Commissioner, for agreeing to be with us today at this special event.

Secondly, I would like to express special thanks to all conference participants who have gathered here with us today. We appreciate the immense sacrifice you have made in time and resources. On behalf of the TAWIRI management, I wish to take this opportunity to express our sincere gratitude for your attendance.

Honorable Minister,

TAWIRI Scientific Conferences are biennial events that aim to bring together prominent and up-coming wildlife scientists and conservationists from across the globe to share information and experiences on wildlife research and conservation. The iInitiation and continuation of these conferences give evidence of the high regard that TAWIRI holds for fulfilling its mandate of disseminating research findings. These conferences, therefore, provides scientific information to stakeholders who are charged with the responsibility of conserving our wildlife resources.

Honorable Minister,

This year's conference theme, ***"Wildlife Research for Enhanced Biodiversity Conservation and Livelihood Improvement"*** reflects prevailing situations and needs in wildlife conservation in the country. Research findings from different parts of the country indicate an increase in human -wildlife interaction adjacent to protected areas, which at most accelerates conflicts. Similarly, severe overgrazing has been reported to cause the conversion of large tracts of pasture into bare land, leading to bush encroachment and spreading of invasive plants, thus reducing the overall forage and carrying capacity of most ecosystems.

The effects of overgrazing have affected not only the biodiversity in the country, but also livelihood strategies, hence, increased over dependence on natural resources for their survival.

Honorable Minister,

TAWIRI in collaboration with other researchers from within and outside the country works together to generate information that is crucial for the conservation of wildlife resources. This is evident in the number of projects that were registered by the Institute. A total of 174 projects with 357 research scientists were registered and supervised in the last financial year 2020/2021. Furthermore, the number of Tanzanian research scientists has been increasing from 125 scientists in the financial years 2012/2013 up to 189 scientists in 2020/21.

Honorable Minister,

At this conference, we will have a total of 180 presentations. Out of these, we have five keynote papers, two round table discussions, two seminars, and twelve parallel sessions where 130 oral presentations will be presented. We also have five virtual presentations and 41 poster presentations to be discussed. Full manuscripts will be submitted to TAWIRI for review process and those that qualify will be published in the 13th TAWIRI Scientific Conference Proceedings.

Honorable Minister,

On behalf of the TAWIRI Management, allow me to express our sincere gratitude to organizations(Sponsors) who made this conference possible.

I would like to mention your ministry through the Wildlife Division, United Nations Environment Programme (UNEP), USIAD-Tanzania, Ortello Business Company (OBC), WWF Tanzania, United Asian group (UAg), and Tanzania People and Wildlife (TPW) as our **premium supporters**.

Likewise, the Arusha International Conference Centre (AICC), TBC and Grumeti Fund as our **silver supporters.**

Our **bronze cohorts** are the Ngorongoro Conservation Area Authority (NCAA), Tanzania Wildlife Management Authority (TAWA), Tanzania Forestry Services (TFS), AWF, Tanzania, Jane Goodall Institute (JGI), Basecamp Research Ltd, Oikos East Africa, Mpingo Conservation and Development Initiative and Frankfurt Zoological Society (FZS).

Others are College of African Wildlife Management–Mweka, National Environmental Management Council (NEMC), REGROW Project, Wild Dog Project, The Nature Conservancy (TNC), Gran Melia Hotels, Mount Meru Hotel, Asilia Lodges and Camps Ltd, Bush 2 Base, Tanzania Natural Resources Forum (TNRF), Nomad Tanzania, Gadgetronix Ltd and Tanzania Tour Operators (TATO).

These organizations are not only our recurrent supporters of this particular event but also support a wide array of conservation activities in various parts of the country. It is our hope that this support will continue to fluorish.

Honorable Minister,

TAWIRI wishes to thank all researchers, academicians, and conservationists who took their time to prepare presentations and attend this important gathering. In the course of this delegation, Honourable Minister, you can pose all kinds of questions to be addressed to support your ministry particularly in the wildlife sector, ranging from the use of technology in conservation to human-wildlife interactions.

Honorable Minister,

With these remarks, I now take the honor to welcome you to address this congregation and officiate the Thirteenth TAWIRI Biennial Scientific Conference.

Honorable Minister, please welcome!

Thank you!

And

MUNGU AWABARIKI SANA

SPEECH OF THE CHAIRMAN OF THE PARLIAMENTARY COMMITTEE FOR LAND, NATURAL RESOURCES AND TOURISM HON. ALOYCE ANDREW KWEZI AT THE OPENING OF THE 13TH TAWIRI SCIENTIFIC CONFERENCE HELD AT THE ARUSHA INTERNATIONAL CONFERENCE CENTRE, ARUSHA, DECEMBER 6, 2021

Hon. Dr. Adv. Damas Daniel Ndumbaro (MP), Minister for Natural Resources and Tourism,

Hon. Mary Francis Masanja (MP), Deputy Minister for Natural Resources and Tourism,

Dr Allan Herbert Kijazi, Permanent Secretary, MNRT, and CC TANAPA

Hon. Agnes Mathew Marwa (MP), Member, Parliamentary Committee for Lands, Natural Resources and Tourism,

Hon. Masood Mohamed Jumah (MP), Member, Parliamentary Committee for Lands, Natural Resources and Tourism

Hon. John Vianney Mongella, Regional Commissioner, Arusha,

Dr. Maurus Msuha, Director of Wildlife, MNRT,

Dr. Eblate Mjingo, Director General, TAWIRI

Mr. Mabula Misungwi Nyanda, Ag. Conservation Commissioner, TAWA

Dr. Freddy Manongi, Conservation Commissioner, NCAA

Prof. Dos Santos Silayo, Conservation Commissioner, TFS

Dr. Revocatus Mushumbusi, Director General TAFORI

Prof. Japhari Kideghesho, Rector MWEKA

TAWIRI Management,

Conference Sponsors,

Keynote speakers,

Excellencies, Head of Institutions and invited delegates,

Conference Participants,

Distinguished guest

Members of the Press

Ladies and Gentlemen

Good Morning!

First and foremost, let me take this opportunity to thank, Dr. Eblate Mjingo – Director General of TAWIRI for inviting me here to take on this important role of opening the 13th TAWIRI Scientific Conference. I would like to express my most sincere appreciation to you, Hon. Minister, and the Ministry as a whole for moral and material support to the Institute.

Ladies and Gentlemen,

On the 9th December 2021 Tanzania will celebrate 60 years of independence. Parallel to this important event, TAWIRI will celebrate 41 years of its existence since its establishment in 1980. I am told that during its establishment, TAWIRI had four staffs members and one research centre that was based in Serengeti National Park. Currently, the institute has 109 staffs members and four major wildlife research centres based in major ecosystems. In addition to these achievements, TAWIRI has managed to organize and host 13 scientific conferences of international standards.

Ladies and Gentlemen,

As leaders, we are responsible for making decisions on behalf of the citizens who elected us from our constituencies. In order to do this correctly, we all agree that research is paramount, as it is the only way one can get reliable information. It is only through research that we can make informed and relevant decisions.

It is also worth noting that the management of our protected areas in Tanzania is the distinctive responsibility of the different management authorities. For these management authorities to achieve sound management, appropriate scientific information acquired through wildlife research is of paramount importance. Given this fact, there is a need for more support for the work done by TAWIRI and wildlife research in general.

Ladies and Gentlemen,

I acknowledge all the sponsors who made this event a success. The attendance of management authorities and researchers is also appreciated. With these few remarks I would like to welcome you all to this conference. We hope that through this scientific congregation we will be able to formulate and implement sustainable solutions to the prevailing and upcoming conservation issues. As the parliamentary committee we will continue to support the initiative taken by TAWIRI and make sure that they execute their mandatory roles.

THANK YOU

SPEECH OF THE DEPUTY MINISTER FOR NATURAL RESOURCES AND TOURISM, HON. MARY FRANCIS MASANJA AT THE OPENING OF THE 13TH TAWIRI SCIENTIFIC CONFERENCE HELD AT THE ARUSHA INTERNATIONAL CONFERENCE CENTRE, ARUSHA, DECEMBER 6, 2021

Hon. Dr. Adv. Damas Daniel Ndumbaro (MP), Minister for Natural Resources and Tourism,

Dr Allan Herbert Kijazi, Permanent Secretary, MNRT, and CC TANAPA,

Hon. Aloyce Andrew Kwezi (MP), Chairman, Parliamentary Committee for Land, Natural Resources and Tourism,

Hon. Agnes Mathew Marwa (MP), Member, Parliamentary Committee for Land, Natural Resources and Tourism,

Hon. Soud Mohamed Jumah (MP), Member, Parliamentary Committee for Land, Natural Resources and Tourism,

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TAWIRI Management,

Conference Sponsors,

Keynote speakers,

Excellencies, Heads of Institutions and invited delegates,

Conference Participants,

Distinguished guest,

Members of the Press,

Ladies and gentlemen.

Good Morning!

Honorable Minister, Ladies and Gentlemen

I am glad to be a part of this congregation, full of scientists and experts in wildlife conservation. It is my first time attending such an event within the ministry and I am sure I will learn a lot and get relevant experience.

Honorable Minister, Ladies and Gentlemen

Recently, the world has witnessed a global financial crisis caused by the COVID-19 pandemic which affected tourism, conservation and research activities. I therefore, urge management authorities, organizations and you scientists to take this as a challenge and start preparing for future calamities by establishing special endowment funds. It is my hope that the crisis has been like a morning wake-up call that has forced us to be more strategic in spending the limited resources that are available when planning research topics as well as conservation activities.

Distinguished Guests, Ladies and Gentlemen

With these few remarks, I would like to welcome Hon. Adv. Dr. Damas Daniel Ndumbaro, Minister for Natural Resources and Tourism, to officiate the opening of the 13th TAWIRI Scientific Conference.

THANK YOU FOR YOUR ATTENDANCE

SPEECH OF THE MINISTER FOR NATURAL RESOURCES AND TOURISM HON. DR. ADVOCATE DAMAS DANIEL NDUMBARO (MP) AT THE OFFICIAL OPENING OF THE 13TH TAWIRI SCIENTIFIC CONFERENCE HELD AT THE ARUSHA INTERNATIONAL CONFERENCE CENTRE (AICC), DECEMBER 6, 2021

Dr. Allan Herbert Kijazi, Permanent Secretary, MNRT,

Hon. Aloyce Andrew Kwezi (MP), Chairperson, Parliamentary Committee for Lands, Natural Resources and Tourism,

Hon. John Vianney Mongella, Regional Commissioner, Arusha,

Dr Maurus Msuha, Director of Wildlife, MNRT,

Dr. Eblate Ernest Mjingo, Director General TAWIRI,

Mr. Mabula Misungwi Nyanda, Acting Conservation Commissioner, TAWA

Dr. Freddy Manongi, Conservation Commissioner, NCAA

Prof. Dos Santos Silayo, Conservation Commissioner, TFS

TAWIRI Management,

Conference Sponsors,

Keynote speakers,

Excellencies, Heads of Institutions and invited delegates,

Conference Participants,

Distinguished guest, members of the press, ladies and gentlemen,

Good Morning!

First and foremost, I would like to thank the Almighty God for making this gathering possible and I am glad that you are all able to be here today, including the online participants.

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 13th TAWIRI Scientific Conference here in Arusha for the first time since my appointment as a Minister of Natural Resources and Tourism. **I feel greatly honoured.**

Conference Participants, Ladies and Gentlemen,

As a host ministry, I wish to take this opportunity to welcome you all to Arusha and this conference in particular. A special welcome is extended to colleagues who have travelled from abroad (Europe, USA, Asia, Australia, East African countries and other parts of Africa just to mention a few) to attend this Conference. Your presence is highly appreciated and signifies your positive support to Tanzania and your commitment to global wildlife conservation. You are most welcome, and it is my hope that you will find the environment conducive enough for your deliberations in the next three days. "KARIBUNI SANA".

Conference Participants, Ladies and Gentlemen,

TAWIRI is mandated to conduct, coordinate and disseminate wildlife research findings to the general public to guide conservation actions. The biennial TAWIRI Scientific Conferences have been very useful in enabling the institute to fulfill its dissemination responsibility. It is my understanding that these conferences are also meant to continually provide up to date research findings that are useful for making informed decisions and promoting the development of the wildlife industry in the country. I am aware that proceedings of the previous conference have been printed, distributed and posted on the TAWIRI website to meet the same purposes and therefore I urge wildlife management authorities to make use of these findings.

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, we will continue to support these conferences to the best of our ability. I would like to take this opportunity to call upon wildlife managers, tour operators, conservationists and development partners to continue participating in these conferences and to make use of the research findings in addressing the ongoing challenges facing the conservation of natural resources in the country.

Conference Participants, Ladies and Gentlemen,

The theme of this conference is "*Wildlife Research for Enhanced Biodiversity Conservation and Livelihood Improvement*". I am told that this theme has thirteen (13) sub-themes out of which 55% of presentations cover areas related to human-wildlife Interactions, habitat and biodiversity conservation and wildlife ecology and ecological interaction.

As a country, I must (and you may also possibly) admit that we are still doing fairly well in wildlife conservation. However, our natural rangelands have been decreasing in size over the last five decades due to changing land use mainly for anthropogenic activities. This has exacerbated human-wildlife conflicts in some parts of the country and my ministry has been working tirelessly with the support of conservation stakeholders, district authorities local communities to reduce the impacts on their livelihoods. I am happy that most of the topics that will be presented are on human-wildlife conflicts. I, therefore, take this opportunity to request all experts in this conference to continue to develop appropriate non-lethal mitigation measures to help reduce conflicts and enhance the co-existence of people and wildlife instead.

Conference Participants, Ladies and Gentlemen,

Appropriate information is required to help trade-offs between livelihoods and sustainable biodiversity conservation. This can only be possible through scientific research which can further enable decision-makers to prioritise and strategies for the future development of both. I believe scientists have the ability to generate useful knowledge and strategies to guide conservation actions and politicians can sell this to the general public and make things happen. Let's work together!

Conference Participants, Ladies and Gentlemen,

Long term changes in climate have been observed worldwide and Tanzania is not an exception. These changes have affected not only biodiversity but also the livelihoods of the local communities living adjacent to protected areas whose lives overwhelmingly depend on natural resources. This creates a vicious circle by which livelihood strategies leads to ecological degradation and later lead to dwindling livelihood assets. Enhancing people's welfare while ensuring sustainable use of natural resources is a challenge that needs to be addressed. I, therefore, urge wildlife management authorities, research scientists and conservationists to take this as a challenge and start preparing future conservation plans for our natural resources under the prevailing circumstances.

Conference Participants, Ladies and Gentlemen,

While I commend scientists for their contribution to wildlife conservation through the generation of scientific knowledge, let me take this opportunity to pose a couple of challenges. First, the loss of wildlife habitat and blockage of wildlife corridors through land conversion and spread of invasive alien species (IAS).

While I am aware that land conversion in historical wildlife ranges is gaining momentum partly due to human population growth and therefore getting the required information on the best way forward is paramount. In regards to the latter, we need to unfold the source, rate of spread, and more importantly how best to prevent from manifesting. More importantly, we must develop predictive models [early warning systems] with the appropriate covariates to help provide a heads-up for quick decision-making. You must all understand that a decision-maker requires not only the right information but also timely information and you, therefore, play must your part and we will play ours to ensure the safety of our planet. At the moment, both the Ngorongoro Conservation Area and Serengeti National Park require immediate attention to safeguard them from invasive alien plant species and you scientists play an important role in this regard. My biggest question to vegetation ecologists and all of us here is that, how did we reach here?

Another very important challenge is the prevailing human-wildlife conflict. In recent years, we have experienced increasing human-wildlife conflict incidences some of which are associated with severe crop damages, human injuries and deaths, property damages and retaliatory killings to of keystone species such as elephants and lions as a result of reduced human tolerance. I urge you all to provide suggestions to my ministry on the best way forward and will take your suggestions seriously.

Conference Participants, Ladies and Gentlemen,

I am informed that this conference has been made possible with generous support from different stakeholders. I would like to recognize my Ministry through the Wildlife Division, United Nations Environment Programme (UNEP), USIAD-Tanzania, Otello Business Company (OBC), WWF - Tanzania, United Asian Group (UAG), Tanzania People and Wildlife (TPW), the Arusha International Conference Centre (AICC), Grumeti Fund, Tanzania Broadcasting Corporation (TBC), Ngorongoro Conservation Area Authority (NCAA), Tanzania Wildlife Management Authority (TAWA), Tanzania Forestry Services (TFS), AWF - Tanzania, Jane Goodall Institute (JGI), Basecamp Research Ltd, Oikos East Africa, Mpingo Conservation and Development Initiative (MCDI), Frankfurt Zoological Society (FZS), College of African Wildlife Management – Mweka, National Environmental Management Council (NEMC), REGROW Project, The Nature Conservancy (TNC), Gran Melia Hotels, Mount Meru Hotel, Tanzania Tour Operators (TATO), Asilia Hotels Ltd, gadgetronix Ltd Bush 2 Base, Tanzania Natural resources Forum (TNRF) and Nomad Tanzania.

Allow me also to thank the organizing committee of the 13th TAWIRI Scientific Conference for making the event successful.

Conference Participants, Ladies and Gentlemen,

As I conclude my remarks, allow me to say a few words. Tanzania like many other countries has been hit by the COVID-19 pandemic and among the most affected industries is the tourism sector, which contributes significantly to the national DGP of up to 17%. My ministry is taking all required precautions and observing the international standards to prevent the spread of pandemics among our people and our visitors. Further, we are doing our best to recover the tourism business while taking the required measures to the best of our ability.

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 within easy reach attractions including Arusha, Lake Manyara, Tarangire,

Mkomazi, 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 home.

With these remarks, I now have the pleasure to declare the 13th TAWIRI Scientific Conference officially opened.

ASANTENI SANA!

CLOSING REMARKS BY THE PERMANENT SECRETARY; MINISTRY OF NATURAL RESOURCES AND TOURISM, DR. ALLAN HERBERT KIJAZI AT THE 13TH TAWIRI SCIENTIFIC CONFERENCE HELD AT ARUSHA INTERNATIONAL CONFERENCE CENTRE (AICC), ARUSHA, DECEMBER 8, 2021

Hon. Aloyce Andrew Kwezi (MP), Chairperson, Parliamentary Committee for Land, Natural Resources and Tourism,

Hon. Agnes Mathew Marwa (MP), Member, Parliamentary Committee for Land, Natural Resources and Tourism,

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Dr. Freddy Safiel Manongi, Conservation Commissioner, NCAA

Prof. Dos Santos Aristaricky Silayo, Conservation Commissioner, TFS

TAWIRI Management,

TAWIRI Management Team,

Conference Sponsors,

Distinguished Guests,

Conference Participants,

Ladies and Gentlemen

It is a privilege to be given this opportunity to give closing remarks for the 13th TAWIRI Scientific Conference. I am also pleased to see the presence of reputable long-time scientists and other researchers from within and outside Tanzania. Your presence here is highly appreciated and signifies your commitment to wildlife conservation.

Ladies and Gentlemen,

This conference attracted more than 400 participants from different parts of the world. This testifies the importance of this forum not only to wildlife scientists but also to management authorities.

Ladies and Gentlemen,

The year's conference theme, "Wildlife Research for Enhanced Biodiversity Conservation and Livelihood Improvement" was meant to cover a wide spectrum of current conservation issues that require scrutiny through comprehensive discussions such as this. These discussions were made possible through the 177 presentations that took place during this conference. Equally, constructive challenges have been raised by researchers to management authorities and policymakers. I ask the management authorities to make effective use of the research findings presented and discussed at this conference for the sustainable conservation of wildlife resources.

Ladies and Gentlemen,

I have noted that most of the presentations fall under the following eight sub-themes:

1.Habitat and Biodiversity Conservation;
2.Human-Wildlife Interactions;
3.Wildlife Ecology and Ecological Interactions;
4.Natural resources policies and good governance;
5.Bee ecology, beekeeping and apitourism;
6.Ecosystem health and wildlife diseases
7.Climate change and ecological resilience; and
8.Industrialization, emerging economic opportunities, infrastructure development and biodiversity conservation.

However, this year's conference had 12 sub-themes, leaving out four sub-theme that had the lowest number of presentations reflecting low attention from you scientists. These sub-themes are:

1.Emerging Technologies and Conservation
2.Water resources and wetland Conservation
3.Monitoring of Wildlife Population and Threatened Species

This is alarming because all of the sub-themes were equally important but some needed more attention, such as Monitoring of Wildlife Population and Threatened Species.

Ladies and Gentlemen,

Organizing a conference such as this is demanding and costly. On behalf of TAWIRI, I would like to express my sincere appreciation to the sponsors of this conference specifically, the Ministry of Natural Resources through the Wildlife Division, United Nations Environment Programme (UNEP), USAID-Tanzania, Otello Business Company (OBC), WWF - Tanzania, United Asian Group (UAG), Tanzania People and Wildlife (TPW), the Arusha International Conference Centre (AICC), Grumeti Fund, Tanzania Broadcasting Corporation (TBC), Ngorongoro Conservation Area Authority (NCAA), Tanzania Wildlife Management Authority (TAWA), Tanzania Forestry Services (TFS), AWF - Tanzania, Jane Goodall Institute (JGI), Basecamp Research Ltd, Oikos East Africa, Mpingo Conservation and Development Initiative (MCDI), Frankfurt Zoological Society (FZS), College of African Wildlife Management – Mweka, National Environmental Management Council (NEMC), REGROW Project, The Nature Conservancy (TNC), Gran Melia Hotels, Mount Meru Hotel, Tanzania Tour Operators (TATO), Asilia Hotels Ltd, gadgetronix Ltd, Bush 2 Base, Tanzania Natural resources Forum (TNRF) and Nomad Tanzania.

Allow me also to thank the organizing committee of the 13th TAWIRI Scientific Conference for working tirelessly and making this conference a success.
I call on other organizations to emulate this spirit of supporting research activities in the country and the coming scientific conferences in particular.

Furthermore, I would also like to take this opportunity to thank you all for finding time to attend and actively participate in this conference here in Arusha. I hope that the outputs of this conference have met the expectations of each one of you.
Ladies and Gentlemen,

I hope that you have had an enjoyable stay in Arusha, the City of Destiny, and Headquarters of the East African Community. If you get time after this conference, I urge you to visit our tourist attractions, including Arusha National Park, Tarangire National Park, Manyara National Park, Serengeti National Park, Ngorongoro Conservation Area to enjoy the magnificent nature that god has endowed the country.
I wish you a safe journey on your way back home and welcome again.

Ladies and Gentlemen,

With these few remarks, I wish you a Merry Christmas and a Happy New Year, 2022, and declare that the thirteenth TAWIRI Scientific Conference closed.

THANK YOU FOR YOUR ATTENTION

RESOLUTIONS OF THE 13TH TAWIRI SCIENTIFIC CONFERENCE, HELD ON 6TH – 8TH DECEMBER 2021, ARUSHA INTERNATIONAL CONFERENCE CENTRE, ARUSHA

Based on the expertise of the conference participants and the mandate of TAWIRI, this conference has the following resolutions;

Recognizing the vision of the government of Tanzania at 60 years of its independence concurrently with the 60 years of the Arusha Manifesto Celebrations, 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 conservation in order to achieve the Global Sustainable Development Goals (SDGs) and the 2030 Agenda for Sustainable Development.

Recognizing Tanzania's rich biodiversity contained in one of the world's largest networks of protected areas and the role of the government, particularly the Ministry of Natural Resources and Tourism (MNRT), in protecting these areas, the addition of five new national parks in the last two years. Including one trans-frontier conservation area (the Akagera-Transfrontier Conservation Area, which transcends from the Burigi-Chato and Ibanda-Kyerwa National Parks in Tanzania).

Recognizing the role of research is to explore and provide alternatives that can be used to guide policy and management and that most of the results of these research are helpful in securing a sustainable future for Tanzania's biodiversity conservation and associated livelihood of the people.

Noting that 62% of people depend on ecosystem services and that tourism contributes to 17% of the GDP. However, it is also evident that increasing degradation of natural resources, due to encroachment and habitat loss is causing declines in some species (giraffe, puku, vultures, etc), leading to increasing conflicts between people and wildlife (e.g. elephants, lions), and it is also evident that we are losing ecosystems from the edges, but not the core.

Recognizing the increasing challenges of managing the boundaries of ecosystems shared between countries- the Trans-boundary conservation areas, there is need for more research-based evidences on the experimental application of different approaches (buffers, deterrents, etc) for the integrated and holistic land-use planning.

Noting the increasing challenges of resource sharing between people and wildlife, there is a need to optimize resources use through adopting new technologies (in agriculture, breeding programmes,waste management, etc.) to increase the capacity of local communities in the governance and ownership of natural resources (e.g., WMA's management).

Recognizing the effects of the COVID-19 pandemic on Tanzania's revenue generation given the fact that 17% of the GPD depends on tourism, the challenge is how do we develop resilient environmentally sustainable economies? We therefore note the need for inter-ministerial and interdisciplinary approaches (livestock, forestry, environmental economics, planners, and lawyers) to sustain measures going forward.

Recognizing the effects of **climate change** are likely to be large and pervasive as reported in COP26 meeting in Glasgow (UK), our biggest challenge would be to ensure resilient and robust ecosystems are sustained.

Recognizing the role of research in meeting the Sustainable Development Goals and the need to halt and reverse biodiversity loss: this 13th TAWIRI Scientific Conference is noting that the world is concerned with the issue of increasing temperatures and droughts, mainly due to the reduction of trees that regulate global temperatures. The government should therefore direct citizens to grow indigenous trees at least around all private lands (along the borders), along the roads and around all water bodies.

Finally but **not** least, we would like to recognize this important anecdote: "In the future, the greatness of a nation will not be judged by its advance in technology or by its achievements in architecture, art, or sports, but by the amount of nature and biodiversity that it can hand over to the next generation." Markus Borner, 2019.

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ACKNOWLEDGEMENT

Tanzania Wildlife Research Institute (TAWIRI) is grateful to various government and private institutions for both material and financial support that made the 13th TAWIRI Scientific Conference a successful event. TAWIRI acknowledges their valuable contributions and is kindly requesting their endless support in the future. A special mention is made to those who prepared and made presentations, round table discussions, symposiums, and workshops that enriched this conference with valuable conservation information. Finally, special thanks go to the Conference Organizing Committee, which worked tirelessly to make the event possible.

SOCIAL DISTANCING INDIVIDUALS IN A TRANSLOCATION RAISES PROSPECTS FOR FILIAL INFANTICIDE IN A CAPTIVE SERENGETI LION PRIDE

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ABSTRACT

***Infanticide** is the behavioral action of the killing of infant offspring by their own conspecifics, usually by parenting or caregivers for gain in reproductive success or fitness and becomes filial when the biological parents are involved. Filial infanticide has been rarely documented in African lions, and few studies attribute the behavior to forms of environmental and anthropogenic stressors that directly and indirectly lead to mortality. A pride of lions in western Serengeti was recently captured for translocation in a stepwise process leading to 11 artificial social distancing events of group members in time (0.47-29 hrs.) and space (0-380 km); invoking a series of antagonistic behaviors at social reintegration (at two open boma captive facilities). At re-integration of the paternal males into the rest of the groups, comprising of cubs, observations of strong anti-infanticidal reaction from the maternal females (by virulently attacking the males) were made. In boma # 1, social distancing time and, boma # 2, social distancing space were the determinant factors. At re-integration of cubs (<90 days old) into the group of maternal/paternal parents at two separate events invoked attacking behavior by the paternal males in the display of infanticidal behavior where in boma # 1, suggesting that the temporal distancing of the males was the best predictor for the behavior and in boma #2 not being the primary cause. The observed events of maternal/ paternal infanticidal behavior may have led to the killing of infant (neonatal) cubs born in boma # 1 in stepwise disappearances. Three theories of the disappearance are placed forward; paternal infanticidal killing, maternal infanticidal killing or caregiver (other group lions) infanticidal killings. The study provides evidence of infanticidal behavior in a lion pride in captivity, after undergoing social distancing following a capture operation for translocation. We recommend moving breeding groups should be avoided to avert prospects of filial infanticide in captivity.*

Keywords: Filial, infanticide, lion pride and social distancing, and translocation.

INTRODUCTION

Infanticide is the behavioral theory behind the killing of infant offspring by their own conspecifics, usually by an adult segment of the population (Schaller, 1972). Adults comprise of both parenting and non-parenting males and females (Estes, 2012). Male infanticide is motivated by sexual competition, where the killing of infant offspring induces early reproduction in target females to the advantage of the infanticidal individuals (Packer and Pusey, 1983). In female infanticide, breeding mothers gain fitness by preserving energy that would be expanded for the rearing of offspring that are predestined to die (Packer and Pusey, 1983). However, infanticide behaviors is not limited to non-parenting conspecifics and is documented to occur in parenting and caregivers also (Agrell et al, 1998). When such killings involve maternal or paternal parents, it is termed filial infanticide (Agrell et al, 1998). When the behavior is displayed in a mothering female, it is termed maternal infanticide. When it involves a fathering adult male, is paternal infanticide (Pusey and Packer, 1994). Filial infanticide is rare and difficult to document, and only a few cases are recorded in species of fish, birds and some mammals. The mammals include bears, felids and some hyanids.

Filial infanticide as behavior is triggered by costs for fitness or reproductive success vs. benefits that are imposed upon the executioner(s). Costs are generally the loss of own offspring, who would otherwise carry the individual's genes for population representation and fitness. But benefits may vary between maternal and paternal parents. Maternally, filial infanticide may benefit mothering females by releasing rearing stressors and retaining protein energy. The former comprises maternal killing and, or abandonment of which in both cases the infant perishes by death. The latter also involves infant killing and, in addition, consumption of carcasses in a strategy for replenishment of expanded protein energy which had been lost in the birthing process. Alternatively, paternal filial infanticide infringes on the male strategy for the maintenance of paternal certainty which justifies paternal investment in the rearing of offspring. Breeding males with lost paternal certainty result to killing their offspring through prospective infanticide.

There is no generally known cause for filial infanticide in animals, however, the behavior has been attributed to forms of environmental and anthropogenic stressors (Agrell et al, 1998). In mammals, some of these causes include conditions when parenting individuals become sensitive to extremely stressful conditions, such as inadequate food supply, calamities such as disease outbreaks, fires, flooding and droughts (Schaller, 1972). Stressful circumstances that are encountered in the birthing and rearing of offspring place energy demands for survival, where mothers are incapable of providing for the young. Such stressors act as diverse triggers for infanticidal behavior (Pusey and Packer, 1994). Rarely does this involve the actual killing of offspring, but more commonly is the abandonment of infant young, leading to starvation and predation mortality (Agrell et al., 1998).

Human interference with animal survivorship is also an attribute triggering factor for filial infanticide in wild animals. Exploited and persecuted populations are affected by 1) high male turnover rate, causing females with infant cubs to abandon them to avoid male infanticide and 2) escape human persecution. Infants suffer starvation and predation as result. Furthermore, human placement of wildlife animals in captivity imposes stressful conditions that mediate acts of parental infanticide. For example, maternal infanticide is perpetuated by human visual and acoustic interference at the birthing and rearing stages of reproduction. Most carnivores social isolate for periods of up to 30-60 days to give birth and only integrate offspring into the rest of the population when have attained significant infant growth. In captivity such social conditions may be inadequate and lacking, causing maternal infanticide.

African lions are renowned for infanticidal behavior among mammals, but carnivores in particular. Though infanticidal behavior is mostly documented in non-parenting adult males, there is increasing evidence of filial infanticide too. Maternal infanticide rarely involves the direct killing of cubs, but rather actions of abandonment which are documented in a number of lion groups. For example, cub survival in prey-scarce areas and seasons of the Serengeti NP is less than 40%, and this is attributed to abandonment-mediated infanticide (Packer and Pusey, 1983). In zoos and other captive holding facilities, maternal lions are known to kill their cubs by abandonment as a result of stressful conditions (poor diet, hygiene, and acoustic and visual disturbance during the birthing process. Paternal infanticide also occurs when parenting males experience pseudo-paternal certainty over the birth or rearing of cub litters and result in attacking and killing. In the wild, this may happen when infants are born soon after the arrival of the new group of males and prior to mating. In captivity, such may result after the social separation of breeding males and pregnant females, where the latter reappears with infant offspring that are unfamiliar to the males.

A pride of lions residing along the western borderline of the Serengeti ecosystem, in Tanzania, was recently captured and translocated in human-lion conflict mitigation (Bartola et al, in review). The capture operation spanned over a time period (number of days) and involved the spatial displacement of individuals in a manner characteristic of social distancing. The operation created artificial social distancing in time and space on a cohesive, breeding pride of 17 lions. Variations in individual capture time and space lead to abnormal social distancing and perturbation, invoking a series of antagonistic behaviors at two periods of group (social) reintegration at two open captive facilities. Aggressive attacking behavior displayed by paternal males towards cubs less than a one-year mimic of paternal infanticide. Alternatively, adult female abandonment behavior of infant cubs mimics maternal infanticide. One or both behavioral events led up to an act of neonatal killing of cubs born inside the facility, characterizing filial infanticide.

Here we highlight the artificial social distancing parameters that were imposed on the paternal and maternal parenting lions and relate them to the diverse triggers of infanticidal behavior displayed in the captive pride to substantiate our claim for the occurrence of filial infanticide in the Serengeti lion pride during translocation by way of:

a. Maternal infanticide was triggered/ caused by the inversed social distancing of neonates (birthing), where there was shortened, premature integration of infant cubs into the rest of the pride.

b. Maternal infanticide triggered by/ due to the lack of denning and human interference activity presented (captivity) stressors to the birthing female.

c. Paternal infanticide results from social distancing of the paternal males, where the loss of prescient memory and, or disownment of impregnation and denial of the female led to simulated prospective infanticide.

d. Paternal infanticide resulting from the premature, artificial integration of infant cubs to the pride of males acted as a stimulus for paternal infanticide.

The lion prides

The lion pride is a close-knit, social unit of adult females, juveniles, cubs and their reigning adult males numbering 17 at the time of extraction (Image 1). The pride is one among 100+ groupings that form the large, contiguous Serengeti lion population, found widespread across the ecosystem. The lions are nominally protected, occupying the western borderline of the ecosystem, in Ikorongo and Grumeti Game Reserves; located between 1° and 3°30°S and 34° and 36°E northern Tanzania (Fig. 1).

Since 2018, the lions have been monitored along the borderline through satellite telemetry, where they are subject to human interference due to conflict with local communities over livestock depredation (Ikanda *et al.,* 2020). In the interim period 2014-19, the pride has sustained lethal PAC and community retaliatory poisoning of up to 9 lions.

In the lean prey season of November-May, the lions endure significant prey scarcity and over time have adapted by attacking adjacent herds of livestock. This is an area of approximately 70.64 km^2 and with a count of 34,000 cattle, goats, sheep and donkeys (SDC, 2018) at a density of 481.31 livestock/ km^2. Whilst inside the conflict area, the lions attain

Plate 1. Captive Serengeti lion pride pending a translocation.

a density of 0.24 lions/km^2 at which point they exerted significant pressure on the local livestock population. Through formations of fission-fusion groups, predation of cattle, goats and sheep in the Makundusi region of conflict took place for 1109 days, killing a total of 59 livestock (at an estimated rate of 5.32 livestock/100 days (Fig. 1)). But the overall impact of depredation on the local livestock population was an off take of close to 1% of the livestock population annually between the years 2016-2020.

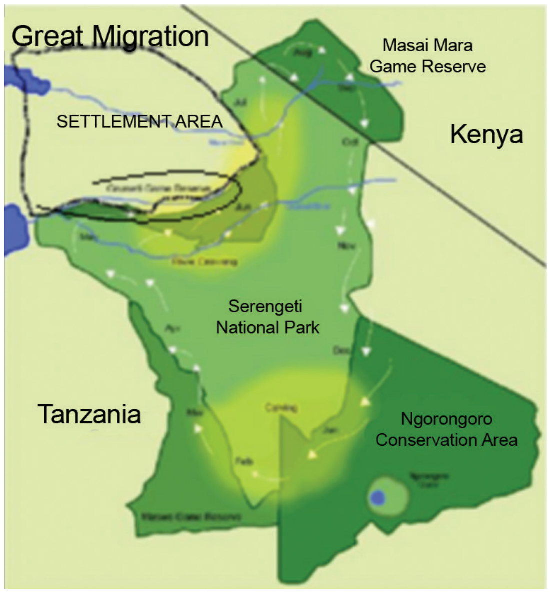

Fig 1. Map of SE in northern Tanzania, depicting the human-lion conflict area (black polygons) that interfaces communities with Ikorongo/Grumeti Game Reserves and Ikona WMA. Adopted from SDLUFP, 2018.

Societal structure

The lion group carried full hallmarks of a pride. There were 20 lions altogether, comprised of 6 adult breeding females, a composite of juvenile females and males numbering 5, and 4 cubs over the age of 18 months. In company, were 2 adult males that have fathered the juveniles and cub litters over the past 2-3 yrs (Plate 1). At the time of extraction, 1 adult female was pregnant with 3 neonatal cubs.

The social distancing of lions in the pride

In November 2019, the Government of Tanzania (GoT) decided to extract the group of lions from the conflict area, following the intensification of attacks on livestock (Ikanda et al., 2020). A capture strategy was devised, that targeted the full extraction of individuals from the conflict area . The activity involved large scale, capture of all pride lions using chemical darting at bait stations. Lion group movements were systematically tracked inside the village lands following livestock attack incidences. Village leaders and herders notified the field teams of impending, ongoing or discovered attack incidences involving the lions by mobile phone. Teams quickly responded by dispatching to the locations and applied the following strategy for capture:

1. Livestock remains or carcasses that were retrieved by herders were acquired for baiting. Initially, the lion groups were provisioned with the meat in order to localize, and restrict their movements into the areas over a period of 13 days. This would enhance the identification of group size and demographics, as well as scaling resources (drugs and transport equipment) for precision capturing.

2. In preceding attacks, attempts were made to GPS collar-tag the groups for future tracking and capturing. Capture

stations were then made by use of bait strung on trees. At sundown, scent trails leading to the bait were made using drags of intestinal meat content in order to lure lions. However, for lions further afield and outside of the scent radius, call-ins using the sounds of a buffalo calf were broadcasted using an amplifier and speakers that were mounted on a vehicle. Broadcast sessions were done in 5-minute bouts, with 5 minutes of silence in between 60 minutes. The sessions were done 6hrly (max.3 sessions) at a station. The baited capture station was inspected for lion visitation/presence every 15 minutes for the entire nighttime hours.

3. Chemical capture. Lions appeared in multiple groups, including both shy and desperate individuals. After attaining relative calmness and consumption of meat by all members, the lions were quickly chemically darted for immobilization.

4. At the first appearance of the groups, two lions (adult female and male) were immobilized and fitted with VHF radio tracking devices/collars. The devices would enable tracking and extraction of all group individuals in a stepwise process that overcomes the challenges of capturing elusive individuals and technical issues with drugs.

5. The subsequent appearance of groups at capture stations resulted in a full capture round-up of the groups. Each capture involved the ground transport of individuals to a holding boma, located 40-60 -minute drive distance.

Table 1 Lion capture events and calculated group social distancing.

	Lions captured				**Social distancing**	
Event	AdF	AdM	Juv	Cubs	Temporal (hrs)	Spatial (km)
1	1	1	-	-	0.47	0
2	4	-	6	1	1.38	15.3
3	-	2	1		7	11.8
4	1	-	-	2	192	14.1
5	1	-	2	4	24	380.3
6	2	-	-	-	24.40	380.3
7	-	-	2	-	25.50	380.3
8	1	-	1	-	26.89	380.3
9	3	-	-	-	27.20	380.3
10	-	1	-	-	28.30	380.3
11	-	1	-	-	29.10	380.3

AdF=adult female, AdM=adult male, Juv=Juveniles (lions < 2yrs old) and Cubs= Cubs (lions <12 months old)

Table 2 Stepwise social integration of lions in captive bomas and observations of infanticidal behavior display.

	Lion social groups				Infanticidal behavior display		
Integration Event	AdF	AdM	Juv	Cubs	Group	Maternal	Paternal
1	1	1	-	-	-	-	-
2	4	-	6	1	-	-	-
3	-	2	1		+	+	-
4	1	-	-	2	-	-	+
5	-	-	-	3*	-	+	+
6	1	-	2	4	-	-	-
7	2	-	-	-	-	-	-
8	-	-	2	-	-	-	-
9	1	-	1	-	-	-	-
10	3	-	-	-	-	-	-
11	-	1	-	-	-	+	+
12	-	1	-	-	-	-	-

* Cubs born within and integrated into the group

Table 2 provides the schedule followed for the extractive removal and social distancing of captured groups. Altogether, there were 11 events of individuals' separations leading to the social distancing of time and space. Social distancing time refers to the period (hrs.) from chemical immobilization, loading to the vehicle, transport and, placement/ recovery in the boma. Social distancing space refers to estimated, straight-line distances (Km) from the point of chemical capture up to the destination bomas. Maternal females were socially distanced 7 times for periods of 0.47-192 hrs. and distances of 0-380 km. On 6 occasions, they were in the company of juveniles and cubs, and once in pair with an adult male. Paternal males were socially distanced 4 times for periods ranging from 0-29 hrs. and distances of 0-380 km.

Social reintegration and observations of infanticidal behavior

At the end of each social distancing session were reintegration events, which brought all of the lions together again as a unit of pride. This involved the stepwise release of lions inside captive bomas and regrouping as a pride. In Table 2, events no.1-4 occurred in boma # 1 in Serengeti and no.6-12 in boma # 2 at Burigi-Chato National Park, northwest Tanzania (Table 2).

There were 8 reintegration events that included maternal females. These were mostly a mixture of females with juveniles and cubs. Alternatively, there was 4 reintegration involving paternal males. These were males mostly on their own. Event # 5 is a special case that involved the birth-in captivity and integration of infant cubs into the group. In contrast with the natural distancing of cubs at birthing, the period required in isolation for infant growth and nursing was short-circuited by the premature integration into the pride (Schaller, 1972).

General behavior observed at social re-integration of the pride member lions

The first reintegration into the group involved an adult breeding male and female, which were introduced back into the pride following a short chemical immobilization and collaring exercise (Table 1). After a social separation period of 0.67 hrs. and 0.15 km distances from the rest of the group, there was no marked infanticidal behavior displayed. Maternal females did not react antagonistically to the recovery from chemical immobilization, and movement of the male into the group; as would be expected in infanticide. Alternatively, the integrated paternal male did not also react antagonistically towards the cubs (> 90 days old) as would be expected in infanticide. The integration served as control, involving the shortest social distancing, in time and space, and measured maternal and paternal behavioral reactions to cubs.

Events 2 and 6 involve the integration of cubs and adult females into bomas #1 and #2 respectively, with the control for paternal males (prior to the introduction of adult males). After a social separation period of 1.38 hrs and 15.3 km from the rest of the group, there was no marked infanticidal behavioral display towards the cubs (> 90 days old) by the displaced females in boma # 1. Similarly, following a social separation period of 24 hrs. and 380.3 km from the rest of the group, there was no marked infanticidal behavioral display towards the cubs (> 90 days old) by the displaced females in boma # 2.

Maternal antagonism towards paternal males at integration

Events 3 (boma #1) and 11 (boma #2) involved the integration of the paternal male coalition into the rest of the groups. In both incidences, there was a strong invoked reaction from the maternal females, which virulently attacked the males, in manners characteristic of infanticide (Table 2). After a short period (3 min) of male submission, calm and normalcy returned. Fig 2 (a) provides social distancing parameters in which the behavior occurred in the maternal females. In boma # 1, social distancing time was more of the determinant factor for the invoked infanticidal behavior. In boma # 2, social distancing space was the prime factor. Both observations suggest social distancing parameters led to either loss in ID memory or trust for the resident males in female lions over the cub safety.

Paternal antagonism towards cubs at integration

Events 4 (boma #1) and 11 (boma # 2) demonstrate the paternal male display of antagonistic behavior towards the cubs, after a lapsing period (5 min-24 hrs) from the maternal attacks (see above). In event # 4, a fresh batch of cubs was integrated into the group, where the adult males quickly began attacking in the display of infanticidal behavior. The behavior persisted until the males were compelled to stop by human acoustic and visual interference (Table 2). In event # 11, after calmness and normalcy, one of the paternal males inevitably singled out a cub and began attacking in infanticidal behavior, invoking strong female defensive behavior and human response.

Fig. 2b shows the social distancing parameters under which paternal antagonistic behavior to the cubs was displayed. In boma # 1, the temporal distancing of the males was the highest of all and is the best predictor for the behavior. The prolonged separation period of paternal males interferes with the prescient memory of offspring, hence making them susceptible to paternal infanticidal behavior. Alternatively, observed spatial distance may not have been an important predictor, as the location of the boma was a short distance (14.1 km) outside of the pride home range in order to lead to substantial geographical disorientation (Do males only recognize offspring when inside of their home ranges? Is paternal certainty influenced by geographical orientations). In boma # 2, conditions were reversed, with spatial distance being 27 times greater in a display of the behavior.

The distancing period was significantly less, hence not being the primary cause in this case.

Neonatal killings by maternal and paternal parents

Observed events of infanticidal behavior in adult females and males led to the killing of infant cubs in course of their integration into the pride inside the boma (Event # 5, Table 2, Plate 2).

No direct observations of paternal or maternal killings were made, however stepwise disappearance of the cubs was recorded and thorough searching (physical) of the boma for verification was conducted on the 3rd day and no visible signs of remains were found.

Three theories of the infanticidal disappearance are placed forward.

1. First, theoretically, the cubs were killed in an act of paternal infanticide. The social distancing of the pregnant female from the males led to the complete erasure of paternal prescient knowledge of the pregnancy, hence paternal certainty. Cubs born were perceived as foreign and

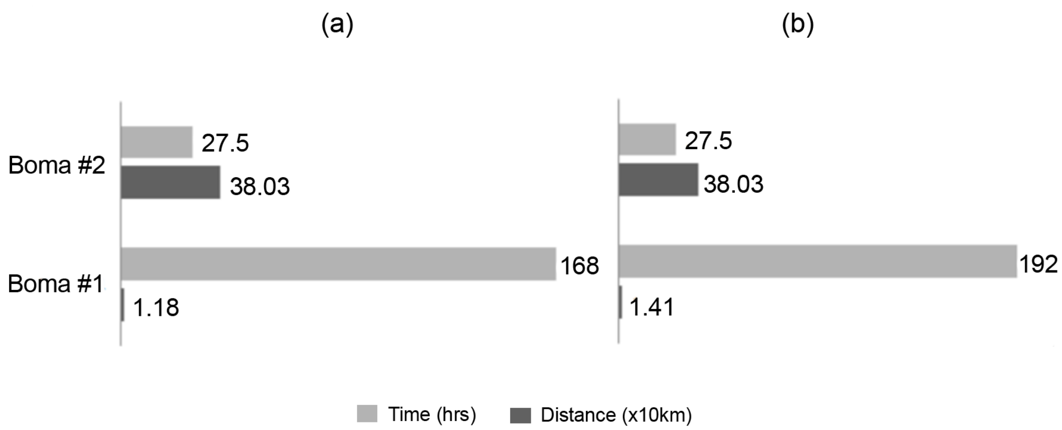

Fig 2. Social distancing parameter estimates observed in the display of infanticidal behavior in a) maternal and b), paternal pride lions

the males responded with prospective infanticidal behavior. This assumption is substantiated by *priori-post* observations of cub-attacking behaviors in the males.

2. The second theory is that the integration of the birthing female into the group disrupted the natural breeding cycle, where infant cubs are socially distanced from the rest of the group until are 6-8 weeks old. The birthing of cubs in sight of males invoked paternal infanticidal behavior. This assumption is substantiated by the fact that the pregnant female was captured whilst undergoing natural birthing isolation and forced-introduced to the males and other pride lions in the captivity of the boma.

3. The third theory is that the inhibition of the female birthing isolation period (by the capture and integration into the boma), in combination with captivity stressors such as human acoustic and visual interferences at the boma may have invoked maternal infanticidal behavior. This assumption is substantiated by the observed stepwise disappearance of cubs, as well as their carcass remains within 3-days of their births.

Plate 2. Neonatal cubs born in boma #1 in captive Serengeti lions

DISCUSSION

Lion's societal structure is greatly affected by the artificial distancing of social members of the group/pride. As conflicts between borderline lion groups in unfenced protected area management systems increase, the subsequent need for translocation will increase. Our study highlights a key challenge for such translocation, especially where entire pride must be captured for extracted removal. Translocation involve capturing individuals in variable gaps of time and distance lengths. The distancing in time and space creates social separation and displacements of group members. Social separating maternal breeding females from their co-breeding males may invoke anti-infanticide behavior among females. Similarly, the social separation of breeding males from their offspring cubs may invoke infanticidal behavior among the paternal males. But importantly, cub birthing in the context of captive environs leads to filial infanticide; maternally by the social interference of other lions and human activity and paternally by prospective infanticidal behavior.

In the present case, the pride was extracted for translocation over 7 capture events, socially distancing maternal females with cubs and their breeding males, as well as paternal males with their pregnant females and cubs. The separations invoked insecticidal behavior at various societal levels of pride. Maternal females were first respondent to impending male infanticide, by the display of vigorous attacking behavior towards the perceived intruding males. The social distancing of the males for 168 hrs and, or 380 km (Fig 2a) distance theoretically affected the certainty of the male residency, hence instilling fear of cub infanticide. Pre-emptive actions were thus taken, where males were attacked in events 3 (boma #1) and 11 (boma #2). Male submissive behavior in both cases led to the easing of tensions and female acceptance of their integration, but the behavior suggests that in both instances the males maintained some levels of prescient knowledge of the females. This showed variations in gender effects of artificial social distancing among adult members of a pride. Nevertheless, the findings are limited to the single sample observation.

Our findings further show the effect of artificial social distancing of paternal males from their cubs (< 12 months). Male social separation from own cubs that are less than a year old for a period of 100+ hrs, as well as the displacement out of pride range/territory severely affected paternal certainty (Fig 2b) among the paternal males. In both instances, potential infanticidal behavior was invoked with the males attacking cubs briefly after their integration. We believe the behavior was triggered by potentially disrupted prescient knowledge of paternal certainty among one, or both males due to social distancing. Paternal certainty is the reason for male investment in the rearing of offspring in mammals and is highly pronounced in lions (Estes, 2012). Such uncertainty is the underlining cause for prospective infanticide in parenting males in the wild and may be human-induced by such artificial social distancing. The antagonistic behavior was displayed by a single member of the male coalition in both cases, demonstrating variability effects among coalition members. Fig 2b indicates similarity in social distancing parameters that were applied in the male coalition and both lions were expected to demonstrate infanticidal behavior. However, observations were made on a single individual, highlighting variability in the loss effects of prescient knowledge on paternal certainty among the coalition members.

The study provides evidence of infanticidal behavior in a lion pride in captivity, after undergoing social distancing following a capture operation for translocation. Circumstantial evidence based on observed male and female infanticidal behaviors is provided to substantiate the occurrence of paternal and, or maternal infanticide in boma # 1. In no doubt were cubs born inside the boma (plate 2) killed by conspecifics shortly after birth, with the prospect of filial infanticide as the plausible cause. The prospect for maternal infanticide is supported by the observed interference in social distancing (time and space) applied in birthing. Pregnant female lions distance themselves in time and space for giving birth (Pusey and Packer, 1994). Cubs are born in isolation from the rest of the pride and are introduced to the pride 6-8 weeks; after attaining growth and movement capability. Then in a slow, gradual process, the maternal female integrates her litter into the pride membership But even # 5 short-circuited and circumvented the social birthing behavior of the lions by the instant integration of infant cubs into the pride, which may have invoked filial infanticidal behavior by the maternal female. The boma was under 24 hrs. human watches and no evidence of fighting and struggle to save cubs from attacking males was observed in the maternal female. As such, the best plausible explanation for neonatal killings is maternal infanticide. In the past 10 yrs., at least 3 incidences of infant lion cub mortality to healthy parents have been recorded in Tanzanian captive facilities. These observations provide grounds for behavioral interpretations, with the prospect of filial infanticide having occurred through maternal abandonment.

Paternal infanticide is less likely to have been the cause, but also possible. Low possibility results from the sudden, unanticipated appearance of the infant cubs to the paternal males that may have precipitated the loss of paternal certainty in the male lions, invoking prospective infanticidal behavior. This line of thinking is supported by the observed female shifting of a remaining cub to a more secure location in event # 5 in an apparent effort to save it. If the prediction is to the right magnitude, paternal males may have killed the cubs each time the maternal female was away and distracted by the accession of food. Such highlights the role of lion denning behavior in female reproductive strategy (Pusey and Packer, 1994).

While literature and research have shown infanticidal behavior in non-parenting male African lions, our observations show also the occurrence of filial infanticide as a consequence of social distancing exercised in translocations, with prospects for both maternal and paternal parents. The observations illuminate how unintentional human disruption of lion pride social distancing bares potential consequences for filial infanticide by breeding males and females in captivity. Managers mitigating human-lion conflict to protect lions from retaliatory killing are limited to the option of extracting entire pride through translocation. The elusive behavior of lions in conflict areas means that they can only be captured in multiple bouts. But each bout creates social distancing of individuals in the pride, of which the isolation period and distance perturbs social behavior. Our study provides a new understanding of the impacts of social perturbation on the reintegration of pride lions in a translocation process. The findings warrant consideration for social distancing effects in lion group translocations, where moving breeding groups should be avoided to avert filial infanticide in captivity.

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YELLOW BABOON DIET FROM THE ISSA VALLEY, WESTERN TANZANIA: DIVERSITY AND ANNUAL VARIABILITY

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ABSTRACT

The genus Papio has a widespread distribution that spans diverse biomes, from Senegalese savannas to Namibian desserts to Ugandan tropical forests, however little is known about their behaviour and ecology in one of the most common habitats of central/southern Africa, miombo woodland. In this study, we summarize the preliminary results of the yellow baboon (P. cynocephalus) diet from the Issa valley, western Tanzania, mosaic woodland. Over six years (2015-2020), we documented baboons to consume at least 57 species, including trees, grasses, shrubs, and mushrooms. Despite this diversity, 60.9% of baboon feeding observations (n= 6360) were from only 18 species of trees. We describe seasonal consumption patterns, especially of these commonly consumed foods, and contextualize Issa baboon feeding ecology against not just what is known from other baboon populations, but also against one of the baboon's primary competitors in this area, sympatric chimpanzees (Pan troglodytes).

Keywords*:* Cercopithecine; Feeding behaviour; Food availability; Miombo woodland; Seasonality

NTRODUCTION

The genus *Papio* has a widespread distribution, from Senegalese savannas to Namibian desserts to Ugandan tropical forests and the highlands of Ethiopia to the Cape of Good Hope [1]. *Papio* comprises multiple species [2] and its biogeography continues to be debated [3].One of those species is the yellow baboon (*P. cynocephalus*): a medium-sized, yellowish,semi-terrestrial species that occupies a variety of habitats, [1,3]. Like nearly all species of *Papio*, there have been decades of research into yellow baboon sociality and ecology, including one of the longest, most productive studies of any nonhuman primate[4].

Across the genus, numerous studies have focused particularly on baboon feeding ecology [5–10] and all reveal similar (genus-wide) patterns of baboons as generalist feeders. Across their distribution, baboons consume a wide number of plant species and parts, and infrequently exhibit carnivory by capturing small mammals and birds [8]. The selective nature of baboon food choice is likely due to a combination of different factors such as plant seasonal availability, nutritional content, digestibility, and energetic demands [11,12]. We summarize in Table 1 what has been described about baboon diet to date.

Understanding baboon diet is crucial for understanding species adaptations, potential competition with sympatric species, as well as developing conservation and management practices [16]. Given that large swaths of south-central Africa are dominated by miombo woodland biomes [17], more information is needed on miombo baboon populations, especially as many of these troops live in formally unprotected areas that are increasingly threatened by human encroachment (cattle grazing, fires, small scale lodging, agriculture, local people harvesting orchid species and poaching) [e.g., 18]

Despite the studies from across baboon distribution listed in Table 1, we know remarkably little about baboon dietary diversity in miombo woodlands. Rhine *et al*. [19] and Norton *et al*. [8] provided extensive descriptions of yellow baboon diet in Mikumi National Park, eastern Tanzania, comprised mostly of savanna grassland and miombo woodland. There, baboons fed on 180 different plant species over five years, including at least one part of each of the top 25 most abundant plants. the seasonal peak in consumed plant diversity was during the wet season and there were seasonal differences in diversity, where the diversity was lowest during the late dry season (October). Overall the most frequently consumed foods were roots from *Vigna* sp and fruits from *Tamarindus* and *Sclerocarya* trees, herbs grasses and green sedges in the wet season and *Tamarindus, Vigna* roots, *Brachystegia* and *Kigelia* in the dry season. Two other, far briefer studies have reported baboon diet from western Tanzania. In a very short (12 days) study during the wet season in Mahale Mountains, baboons were observed to consumed 36 different species, of which 18-57% overlapped with chimpanzees food. From Gombe National Park (Tanzania), an 18-mo study revealed some overlap with Mahale baboon foods. Gombe baboons consumed over 62 species of plant, relying heavily on *Mangifera indica*, *Elaeis guineensis*, and *Ficus* sp. all year, *Acacia hockii* and *Pterocarpus maningus* in the dry season, and *Antidesma venosum* and *Smilax krassiauna* in the wet season [9]. Individuals from both Mahale and Gombe consumed invertebrates and at Gombe, a diversity of vertebrate species, including fruit bat, bushbuck, and weaver bird eggs [9].

Here we build on these studies of Tanzanian baboons, describing a significantly longer baboon diet dataset from the Issa Valley (also in western Tanzania), a savanna- mosaic, miombo woodland habitat. We contextualize these data with reports from other baboon diet studies and also briefly investigate potential feeding competition between sympatric baboons and chimpanzees (*Pan troglodytes schwenifurthii*). We report on baboon dietary diversity, seasonal changes in plant consumption, and implications for behavioural diversity across the genus.

Table 1. Baboon diet studies, with country, habitat, and consumed species identified

Troop name/location	Country	Habitat	Total species consumed	Study period	Source
Alto`s group/ Amboseli NP	Kenya	complex mosaic of woodland and grassland	>30	11 months	[5]
Viramba troop/Mikumi NP	Tanzania	Woodland and grassland	>180	5 years	[8]
Mtshopi troop/ Mkuzi Game Reserve	South Africa	Woodland	92	1 year	[13]
Mchelelo troop/ Tana River Primate National Reserve(TRPNR)	Kenya	Savannah and forest	≈62	55 months	[14]
Sonso troop/ Budongo Forest Reserve	Uganda	Forest	51	20 weeks	[10]
Beach troop/Gombe NP	Tanzania	Forest	>62	18 months	[9]
MahaleMountans NP	Tanzania	Forest	36	12 days	[15]

MATERIALS AND METHODS

Study area

We collected data in the Issa valley, located in the Tongwe West Forest Reserve (Figure 1). In the core study area, the altitude ranges from 1050 to 1800m. Issa is characterized as a miombo mosaic habitat, dominated by *Brachystegia* and *Julbernardia* tree species, intersected by patches of swamp, grassland, evergreen gallery and thickest riparian forest. There are two seasons: a dry season (May – Oct) and wet season (Nov – Apr), when nearly all rain falls (mean from 2015-2019 = 1245mm/year. Mean annual temperature is 19.9^{o}C, with a range of 11^{o}C to 35^{o}C (Figure 2). The ecosystem hosts diverse medium-large mammalian fauna, including chimpanzees, leopard (*Panthera pardus*), wild dogs (*Lycaon pictus*), Roan antelope (*Hippotragus equinus*), and eland (*Taurotragu sderbianus*) among others.

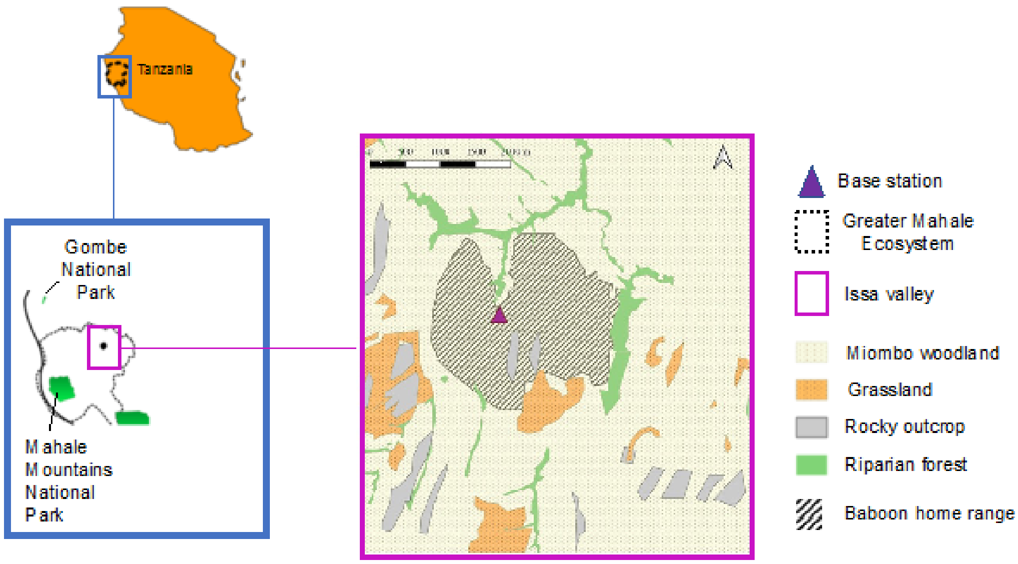

Figure 1. Map of the study area, including vegetation class and baboon annual home range

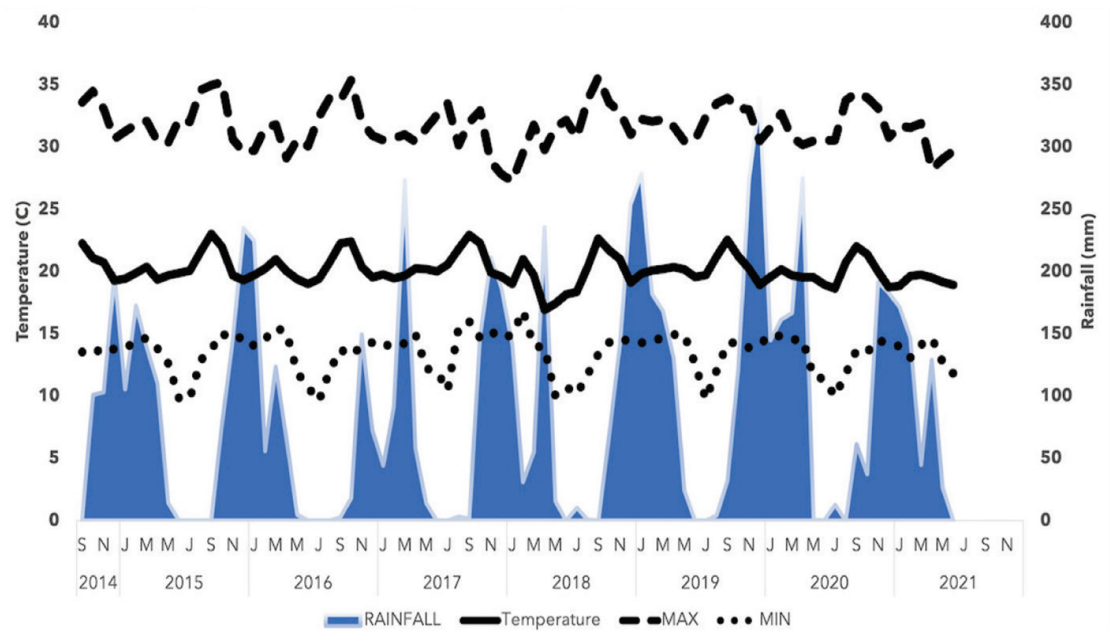

Figure 2. Environmental variability (temperature in black, rainfall in blue) over the study period

Study subjects

Issa's baboons were first habituated in 2011 and have been followed regularly since 2012. The current "camp troop" (CT) home range is ~ 4km^2 and exhibits minimal change across seasons [21]. The troop size has oscillated between12-18 individuals since 2015.

Data collection

We followed CT an average of four days/ month each month (rang: 1-6 days) from January 2015 – December 2019 (48 months). We located the group through an RF signal emitted by a collar worn by two troop members or from opportunistic encounters with the troop on 'search days.' When the troop was located, we collected focal data on a randomly selected individual every five minutes, including the focal's GPS location, behaviour, and in which vegetation type the individual was observed (riparian forest = 'closed'; woodland, swamp, grassland = 'open').When the individual was feeding, we recorded what plant part the individual was eating and from which plant species. Individuals were followed from sleeping site to sleeping site. We designated food items as trees, shrub, invertebrates, mushrooms, grasses/sedges and roots. Roots included rhizomes, root stalks, corms, and unidentified underground items which baboons obtained through digging, but were too small for observers to identify. All ingested plants were identified whenever possible and at times, specimens collected were identified and classified by an experienced botanist.

RESULTS

In total, we collected 6360 total feeding scans across 212 days of follows, from 18 different individuals. Individuals were observed feeding on various food sources from plants to invertebrates. We documented the consumption of 59 naturally occurring food items, of which 57 were from plant sources (trees, shrubs and lianas – see Table 2) and from these only 47 were identified to genus and or species level. 18 plant species accounted for 60.9% of the total feeding observations and only four more foods (22 total) comprised 0.5% or more of total feeding observations Table 3.

Table 2: Food items in the diet of the yellow baboon from the Issa valley

Scientific Name	Family	Leaves	Fruit	Seed	Stem	Bark	Root	Flower	Sap	Life Form
Aframomum mala	Zingiberace		√							Shrub
Afrocanthium burttii	Rubiaceae		√							Tree
Albizia antunesiana	Fabaceae			√						Tree
Anisophyllea boehmii	Anisophylleaceae		√							Tree
Annona senegalensis	Annonaceae		√							Tree
Aspilia bidens	Asteraceae							√		Shrub
Brachystegia boehmii	Fabaceae	√		√						Tree
B. bussei	Fabaceae			√						Tree
B. microphylla	Fabaceae			√				√	√	Tree
Brachystegia speciformis	Fabaceae			√						Tree
Brachystegia spp	Fabaceae			√						Tree
Bridelia micrantha	Euphorbiaceae							√		Tree
Canthium hispidum	Rubiaceae		√							Tree
Combretum molle	Combretaceae	√	√	√						Tree
Dalbergia nitidula	Fabaceae							√		Tree
Euphorbia polycantha	Euphorbiaceae					√				Tree
Garcinia huillensis	Guttiferae		√							Tree
Hexalobus monopetalus	Annonaceae		√							Tree
Isoberlinia angolensis	Fabaceae			√						Tree
Julbernardia globiflora	Fabaceae	√		√						Tree
J. unijugata	Fabaceae			√						Tree
Keetia gueinzii	Rubiaceae		√							Tree

Scientific Name	Family	Leaves	Fruit	Seed	Stem	Bark	Root	Flower	Sap	Life Form
Landolphia owariensis	Apocynaceae		√							Climber
Lannea schimperi	Anacardiaceae		√							Tree
Lanneaspp	Anacardiaceae		√							Tree
Leptactina benguelensis	Rubiaceae		√							Shrub
Macphersonia grasilis	Sapindaceae		√							Tree
Monanthotaxis poggei	Annonaceae		√							Tree
Newtonia buchananii	Fabaceae			√						Tree
Parinari curatellifolia	Chrysobalanaceae		√							Tree
Pterocarpus angolensis	Fabaceae									Tree
P. tinctorius	Fabaceae			√				√		Tree
Saba comorensis	Apocynaceae		√							Climber
Strychnos	Loganiaceae		√	√						Tree
S. innocua	Loganiaceae		√							Tree
S. pungens	Loganiaceae		√							Tree
Syzygium cordatum	Myrtaceae		√							Tree
Sy. guineense	Myrtaceae		√							Tree
Tephrosia spp	Fabaceae			√						Shrub
Thespesia garckeana	Malvaceae	√								Tree
Upaca kirkiniana	Euphorbiaceae		√							Tree
U. nitida	Euphorbiaceae		√							Tree
Vepris trichocarpa	Rhizophoraceae		√							Tree
Vitex mombassae	Verbenaceae		√							Tree
Vitex sp.	Verbenaceae		√							Tree
Xeroderris stuhlmanii	Fabaceae			√				√		Tree
Ximenia caffra	Olacaceae		√							Tree
Ziziphus abyssinica	Rhamnaceae		√							Tree

Table 3 - Species accounting for 0.5% or more of time spent feeding

Scientific Name	Percentage
Brachystegia microphylla	21.6%
Julbernardia globiflora	10.5%
Euphorbia polycantha	4.5%
Xeroderris stuhlmanii	3.5%
Upaca kirkiniana	3.1%
B. speciformis	3.0%
Parinari curatellifolia	1.9%
Brachystegia. spp	1.70%
Anisophyllea boehmii	1.6%
Upaca nitida	1.5%
B. boehmii	1.4%
*Vitex*sp.	1.1%
Lannea schimperi	1.1%
Keetia gueinzii	1.0%
Garcinia huillensis	1.0%
Afrocanthium burttii	0.9%
Pterocarpus tinctorius	0.8%
Syzygium guinesse	0.8%

Although baboons consumed foods from trees, shrubs, grasses, roots, mushrooms, and invertebrates, trees were the primary source (64.7%) of food for Issa baboons, ahead of grasses (14.6%), mushrooms (7.8%), and invertebrates (6.1%). Shrubs (0.51%) and lianas (0.14%) comprised the most infrequently consumed foods. Over 50% of all consumed species were from two families: Fabaceae (43%) and Euphorbiaceae (9%), with *Brachystegia microphylla* (Fabaceae) accounting for 21.6% of all feeding observations. Baboons consumed young leaves, flowers, seeds and sap of this key species.

Baboons were rarely observed consuming vertebrates, while invertebrate feeding contributed to a very modest proportion of feeding data (0.61%). We documented individuals consuming unidentified bird and at least once a rock agama (*Agama agama*).

Seasonality

We found seasonal differences in baboon dietary diversity and composition. A total of 51 food sources were consumed during the wet season (November-April) compared to 46 food sources during the dry season (May-October). 35 species were consumed in both seasons, with 47 only consumed in the wet and 43only consumed in the dry (figure 3). The distribution by life form of the species consumed differed across the seasons. Of the 51 total wet season foods, 51.8% were trees, 19.5% mushroom17.6% grasses, 7.3% roots, 3% invertebrates, 0.7% shrub, and 0.1% lianas. Of the 46 total dry season food sources, 71.7%were trees, 12.8% grasses, 7.9% invertebrates, 6.1% roots, 0.9% mushroom, 0.4% shrub, and 0.2% lianas. Predominantly, baboons relied on young leaves and flowers during the wet season, with species *B. boehmii* representing the most frequently consumed. In the dry season, they relied most on seeds, dominated by *B. microphylla, Julbernardia globiflora* and *Xeroderris stuhlmanii.* Sap was consumed in both seasons, and mostly from *B.microphylla*). Like in Budongo [10], mushrooms appeared to be eaten in preference to other food whenever they were available and represented the most consumed food during the wet season.

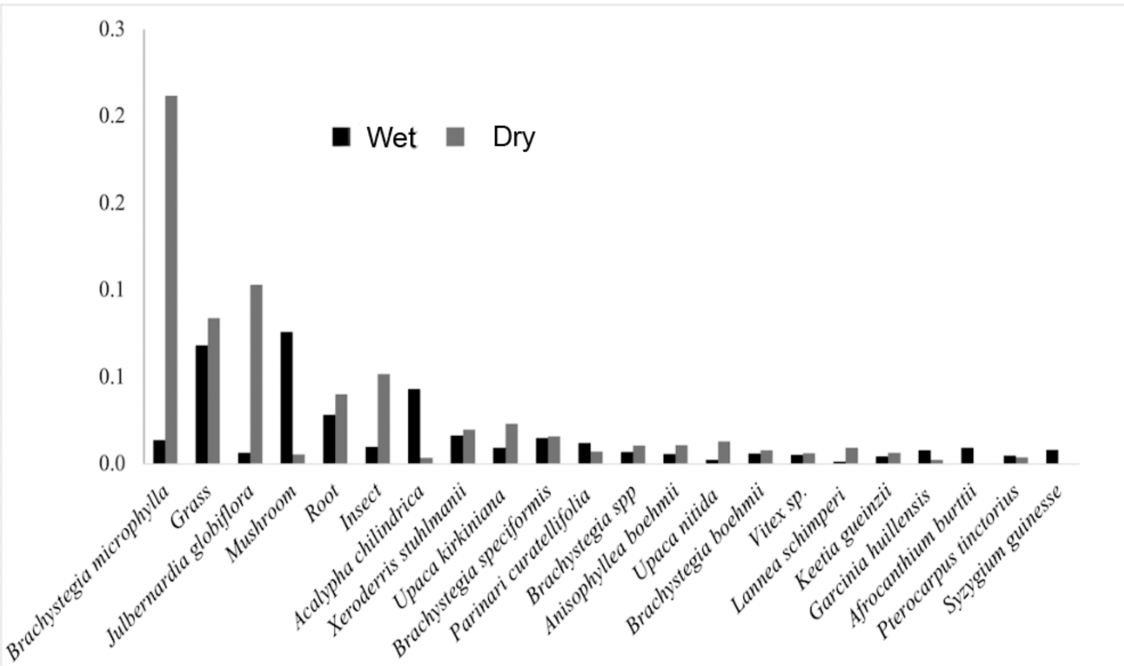

Figure 3. Comparison of baboon diet for wet and dry season of food items accounts 0.5% and above

DISCUSSION

In this study, we investigated yellow baboon diet over five years to assess the diversity of foods consumed and the seasonal variation of those consumption patterns. The 59 foods that we documented are similar to what has been reported in other (regional) studies (Table 1). Compared to a study from the geographically closest troop, in Mahale Mountains National Park, Issa baboons consumed more *B. microphylla* but do not consume *Saba florida,* which is the most eaten food by Mahale baboons according to [15]. The only species of *Saba* at Issa is *S. comoroensis*, which is found mostly in riparian forests and thus represents only a small part of Issa baboon diet. There was no seasonal analysis from Mahale with which to compare. Compared to another geographically close troop (l<100 km) in Gombe National Park, Issa baboons showed no similarities in important food types The Gombe baboons rely mostly on *M. indica, E. guineensis*, and *Ficus* sp. while the Issa baboons rely on *B. microphylla*. Vertebrate consumption is higher in Gombe baboons compared to Issa baboons as well. It should also be noted that whilst the miombo woodlands atop the Gombe hills likely host similar species to Issa, Ransom's data were collected from the 'Beach troop', along Lake Tanganyika, relatively far from those woodlands with other troops inhabiting the areas between them. Consequently, beach-lined mango and palm trees were far more available and important to the 'Beach' troop compared to troops that range over the woodlands, further uphill from the coastline. Subsequent data from more inland troops may reveal greater similarity to Issa.

We observed no egg predation and only minimal consumption of vertebrate prey, with Issa baboons, observed consuming an unidentified bird and a rock agama (*Agama agama*). In contrast, baboons from across their distribution consume a diversity of fauna, including antelope, hares, bats, and other monkeys [reviewed in 22,23]. In Budongo, baboons were observed to capture and consume a domestic fowl [10] and broadly, *Papio* is widely characterised as a pest/scavenger when it coexists with people [24,25]. At Issa, despite nearly 10 years of study and a range that includes the permanent research station, we have not observed a single instance of raiding human food stores or food waste areas (Piel, Stewart pers. observation).

Mushrooms comprised an important part of Issa baboon diet, entirety restricted to the wet season when mushrooms are available(figure 3) In other parts of Tanzania,[26,27] and across the region [10] baboons also consume mushrooms and this is thus an important food for both baboons and chimpanzees at Issa (Piel& Stewart, unpublished data). At Issa however, the proportion of mushrooms in baboon diet (>13%) is far larger than reported elsewhere, <1% [Amboseli - 26] and <5% [10].

Similarly, the frequency of invertebrate feeding at Issa (6.1%) was higher than that reported in Amboseli (1%) [5]. At Issa, like elsewhere [28], baboons expanded their dietary repertoire by plucking, digging and peeling foods. For example, they dug for roots, rhizomes, corms, and tubers as well as peeled and cleaned underground plant parts. Digging and feeding on underground items was not common in Gombe baboons [9]data describing chimpanzee diets stem primarily from forest-dwelling communities, and we lack comparative data from chimpanzees that live in mosaic habitats that more closely resemble those reconstructed for Plio-Pleistocene hominins. We present data on the diet of a partially-habituated community of open habitat chimpanzees (Pan troglodytes schweinfurthii, but this is very common in Issa and also Cape Reserve (RSA) baboons [30], among others. These behaviours may allow them to reduce competition with sympatric chimpanzees, with whom they are known to compete for key foods in other regions[15]. Whereas there are reports from both the wild [31]the development of the distinctive skull and tooth morphology of the genus Australopithecus, and the evolution of the genus Homo by serving as \"fallback foods\" exploited during periods of food shortage. These hypotheses have been tested mostly by morphological, isotopic, and microwear analyses of hominin bones and teeth. Archaeological evidence of USO digging technology is equivocal. Until now relevant data from studies of chimpanzees, useful in behavioral models of early hominins because of their phylogenetic proximity and anatomical similarities, have been lacking. Here we report on the first evidence of chimpanzees using tools to dig for USOs, suggesting that exploitation of such resources was within the cognitive and technological reach of the earliest hominins. Consistent with scenarios of hominin adaptation to savannas, these data come from Ugalla (Tanzania and captivity [32] of chimpanzees using tools to dig for food, the behaviour is extremely rare. This ability of baboons to extract underground plant parts may be a major advantage to allow them to access foods sympatric animals like chimpanzees do not.

Previously, Piel and colleagues [29] described 69 plant species consumed by Issa chimpanzees. Of these, 27 overlap with the results from the current study, and of those 27 species 18 species are woodland species and a further nine of these are listed in the top 25 most consumed foods by chimpanzees. However, unlike Issa chimpanzees, Issa baboons do not exploit riparian patches as part of their ranging or foraging. Issa baboon range is comprised of <2% evergreen riparian forest [21], compared to ~12% for chimpanzees. Consequently, some of the most important foods for chimpanzees [e.g., Ficus, Flacourtia - 29] are absent from our baboon feeding list. Instead, key foods for which these primates compete include woodland-growing Parinari curatellifolia, Strychnos innocua, Vitex doniana, V. mombassae and Anisophyllea boehmi (Table 4). Baboons may also take advantage of their more folivorous diet, for instance, spending more time consuming the seeds and leaves B. Microphylla than any other species; B. microphylla is not in the top 25 most consumed species of chimpanzees [29].

Study of baboon diet is essential to our understanding of the ecology, morphology, and behaviour of the taxa, especially its geographical behavioural diversity [26, 14]. More, identifying key foods can be a starting point to understanding broader, ecosystem-wide processes, including any role baboons play in ecosystem services [e.g., as seed dispersers - 33] and competition dynamics with sympatric species [with e.g., chimpanzees - 15].Moreover, baboon dietary choices can play an important role in forest regeneration [33].

Despite these early results, there is still much to learn about Issa baboon diet. Subsequent work could incorporate the nutrient composition of baboon foods as well as phenology to identify food preferences, fallback foods, and temporary periods of dietary overlap between baboons and chimpanzees.

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Table 4. Woodland dietary species overlap between baboons and chimpanzees and importance rank for each species

Species	**Family**	**Baboon food rank**	**Chimpanzee food rank**
Anisophyllea boehmi	Anisophylleaceae	12	16
Annona senegalensis	Annonaceae	32	21
Brachystegia microphylla	Fabaceae	1	
Brachystegia sp.	Fabaceae	12	
B. spiiciforms	Fabaceae	10	
Combretum sp.	Combretaceae	59	
Hexalobus monopetalus	Annonaceae	38	
Julbernardia globiflora	Fabaceae	3	
Parinari curatellifolia	Chrysobalanaceae	11	5
Pterocarpus tinctorius	Fabaceae	21	
Strychnos innocua	Loganiaceae	23	6
Thespesia garckeana	Malvaceae	59	24
Uapaca kirkiana	Euphorbiaceae	9	22
U. nitida	Euphorbiaceae	14	23
Vitex doniana	Verbenaceae	16	8
V. mombassae	Verbenaceae	28	8
Ximenia caffra	Olacaceae	24	
Ziziphus abyssinica	Rhamnaceae	56	

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STATUS OF LAND USE/LAND COVER CHANGES AND PERCEIVED CHANGES IN LARGE CARNIVORE POPULATIONS IN VILLAGES IN THE EASTERN SERENGETI ECOSYSTEM

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ABSTRACT

One of the greatest threats is land-use change, which results in the loss of natural habitat, isolation of protected areas, and increasingly pervasive edge effects. Working within the greater Serengeti ecosystem, Tanzania, satellite images were used to quantify trends in land use and land cover change in two-time steps (1989 and 2019). This was conducted for six study villages in the Loliondo Game Controlled Area (LGCA); three in the Maasai tribal area (pastoral) and three in the Sonjo tribal area (agropastoral). To relate these changes in land use and land cover with carnivore population trends, 180 respondents aged over 45 years were interviewed randomly, about their perceptions of local large carnivore population trends over the past 30 years. For three decades, agricultural expansion in the three closest villages (Maasai tribe) from the Serengeti National Park border (SNP) increased by 95%, whereas for the furthest three villages (Sonjo tribe), they increased by 90%. Furthermore, forestland decreased by 61% in the three closest villages whereas, for the furthest three villages, it decreased by 30%. Respondents reported that population sizes of spotted hyena (Crocuta crocuta) and African wild dog (Lycaon pictus) were stable, whereas lion (Panthera leo), cheetah (Acinonyx jubatus), and leopard (Panthera pardus) populations had declined.

Keywords: human population increase; land cover; land use; large carnivore; Serengeti

INTRODUCTION

Globally, humans occupy 83% of the available land area, while the remaining 17% receives some level of protection (Sanderson *et al*., 2002). The level of wildlife protection within such protected areas differs greatly (Lewis et al., 2021). Human activities negatively impact as much as 60% of the wildlife in protected areas (Brondizio *et al*., 2019; EMH, 2005; Sanderson *et al*., 2002; Tscharntke *et al*., 2002; van der Esch *et al*., 2017; Wessels *et al*., 2000; Williams *et al*., 2016). Human population increase is currently the most serious threat to biodiversity in most ecosystems (Bongaarts, 2009; Mbau, 2013; Woodroffe, 2000). Human population growth drives agricultural expansion, which ultimately transforms natural wildlife habitats into croplands and rangelands for livestock (Mbau, 2013; Sanderson *et al*., 2002; Treves & Karanth, 2003; van der Esch *et al*., 2017). As a consequence, a large proportion of natural habitats have been turned into croplands and pasture fields in recent decades (EMH, 2005; van der Esch *et al*., 2017; Woodroffe, 2000). Moreover, human activities may also lead to habitat fragmentation, reducing the connectivity to other habitats supporting wildlife populations (Nyssen *et al*., 2004; Woodroffe & Frank, 2005).

Human activities have directly impacted many protected areas across the African continent (Achard *et al*., 2002; Nyssen *et al*., 2004; Veldhuis *et al*., 2019; White *et al*., 2000; Woodroffe & Ginsberg, 1998) and populations of different species are declining at unprecedented rates (Brondizio *et al*., 2019). Human population increase negatively impacts animal populations, especially where people and wildlife share the same landscape (Mbau, 2013; Treves & Karanth, 2003; Williams *et al*., 2016; Woodroffe, 2000). For instance, 75% of the lion (*Panthera leo*), cheetah (*Acinonyx jubatus*), African wild dog (*Lycaon pictus*), and Ethiopian wolf (*Canis simensis*) ranges have been lost due to human population increase (Ray *et al*., 2005). From the 19th century to the present, populations of large carnivores have faced enormous declines (Brondizio *et al*., 2019; EMH, 2005). Large carnivores are species that require large home ranges, however, their ranges are shrinking due to pressure from human activities (Chapron *et al*., 2014; Di Minin *et al*., 2016; Linnell *et al*., 2001; Williams *et al*., 2016; Woodroffe, 2000). Habitat loss and degradation of the large carnivore ranges have led to severe declines in most of these iconic species' distributions (Di Minin *et al*., 2016; Woodroffe, 2000; Woodroffe & Ginsberg, 1998). For instance, before 19th century African wild dogs were found across the whole country of South Africa, while today they are found only in small isolated protected areas (Lindsey *et al*., 2004).

Moreover, the prey base of large carnivores has also declined and their habitats have been fragmented, resulting in an increased frequency of encounters between large carnivores and humans (Mbau, 2013; Treves & Karanth, 2003; Woodroffe, 2000). As these encounter rates increase, conflicts between large carnivores and humans increase, as these species attack livestock and threaten people's lives and livelihoods (Ikanda & Packer, 2008; Kebede *et al*., 2016; Kissui, 2008). For instance, persecution by humans led to a 47.6% decline of cheetahs on Namibian farmlands over eight years (Marker *et al*., 2003). When humans and large carnivores share the same landscape, conflicts are common (Dickman, 2010; Dickman *et al*., 2014; Kebede *et al*., 2016). Large carnivore populations are managed by the use of different approaches (Laverty *et al*., 2019; Nyssen *et al*., 2004; Treves & Karanth, 2003). A study on lions in eleven African countries by Packer *et al*., (2013) concluded that lions in unfenced reserves were more sensitive to surrounding human populations, resulting in lower lion densities than in fenced reserves. In contrast, many conservationists recommend a coexistence approach in the face of the current human population increase across the globe (Chapron *et al*., 2014; Di Minin *et al*., 2016; Lindsey *et al*., 2013; Treves & Karanth, 2003), especially in the areas where humans and large carnivore share the same landscape (de Souza *et al*., 2018; Lindsey *et al*., 2013; Linnell *et al*., 2001; Mbise, 2021; Ronnenberg *et al*., 2017; Woodroffe *et al*., 2005).

The focus of this survey was to estimate the reported decline of large carnivores during current land use changes resulting from the human population increase. This study was conducted in Loliondo Game Controlled Area (LGCA), which borders Serengeti National Park in northern Tanzania. The study hypothesized that the reported declining trend in large carnivore numbers will be higher in the three villages which are further away from the Serengeti National Park (SNP) border (Sonjo tribe; agro-pastoral) which are highly populated, compared to the three villages closer to SNP border (Maasai tribe; pastoral), which are less populated (people/km^2).

MATERIALS AND METHODS

Study area

The study was conducted in Loliondo Game Controlled Area (LGCA), in northern Tanzania (Fig. 1). Six villages were surveyed, three in the Maasai tribal area (Ololosokwan, Soitsambu, and Oloipiri) and three in the Sonjo tribal area (Sale, Samunge, and Yasimdito). The main activity of the Maasai people is pastoralism, while the Sonjo people are mainly agropastoralists (Mbise, 2018). Large carnivores found in the area are lion, leopard (*Panthera pardus*), cheetah, spotted hyena (*Crocuta crocuta*), and African wild dog (Holdo *et al*. 2010, Valkenburgh and Wayne 2011).

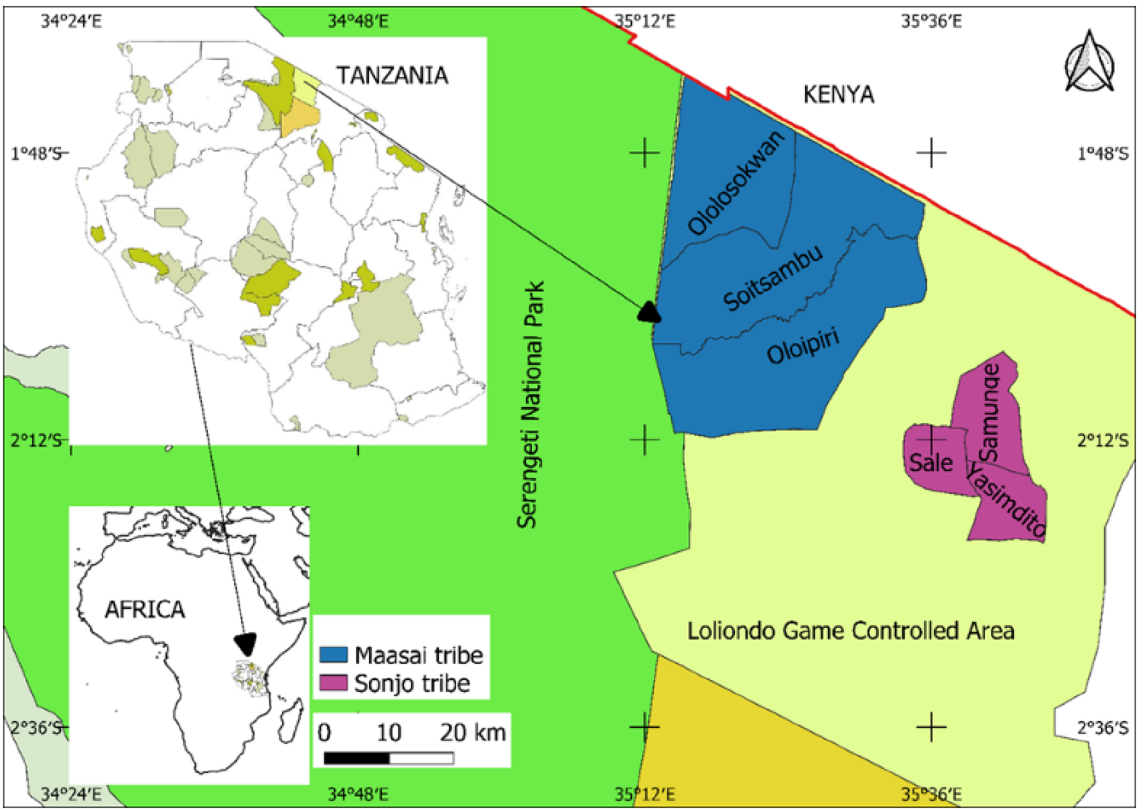

Figure 1. A map showing the six villages being studied in the eastern Serengeti ecosystem

The local human population growth rate is high. For example, in 2019 the population in the six villages were 42431 people, projected an annual increase of 7% (NBS, 2020) (Fig. 2). With this high rate of population increase in the area, demand for land increased proportionally, especially for subsistence farming, which again leads to major land use changes (Maddox, 2003; Mbise, 2022a; Veldhuis *et al*., 2019).

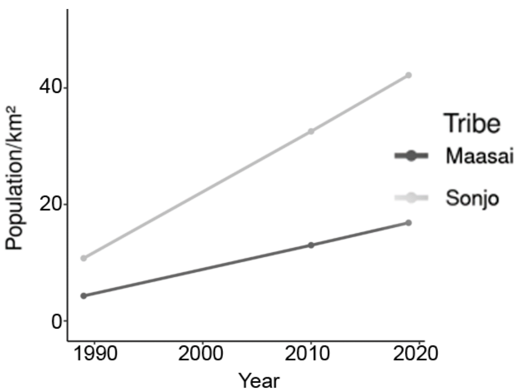

Figure 2. Human population density (people/km^2) for the six surveyed villages, three Maasai villages (dark grey line) and the three Sonjo villages (light grey line) (NBS, 2020)

Data collection and analysis

Image data was gathered from the United States Geological Survey (USGS, https://www.usgs.gov/core-science-systems/nli/landsat/landsat-data-access) to quantify the land use changes during the last three decades in the eastern Serengeti ecosystem. Satellite images at 30 meters spatial resolution were used to process the land use and land cover change trends from 1989 to 2019 in two-time steps: Landsat on March 4, 1989, and Sentinel on February 2, 2019. Timing within the year (month) was maintained as close as possible to ensure similar phenology. Land use and land cover change were calculated based on the tribal area in square kilometres (Maasai and Sonjo), each having three villages. A total area of 1974 km^2 was surveyed, Maasai area covering 1612 km^2 and Sonjo area covering 362 km^2. Surveyed area was categorized into five classes: agriculture, forestland, grassland, shrubland, and woodland. Ground truthing was also conducted using Global Position System (GPS) (eTrex® Vista HCX), classifying different habitats (Table 1) to corroborate image analyses. Since these classes were relatively homogeneous, there was no need of taking many validation points.

Table 1. Ground validation points against class used during accuracy assessment

Ground Truth (Pixels)						
Classified - Data	**Cropland**	**Forestland**	**Grassland**	**Shrubland**	**Woodland**	**Classified - Total**
Agriculture	12	0	0	0	0	12
Forestland	0	4	0	0	0	4
Grassland	0	0	9	0	0	9
Shrubland	0	1	0	7	1	9
Woodland	0	0	0	0	3	3
Total	12	5	9	7	4	37

In July 2017, 180 respondents aged 45 years and above were interviewed, of which 90 Maasai respondents and 90 Sonjo respondents, in three villages in each tribal area; Fig.1) about their views on the change in large carnivore populations over the past 30 years. The interview exercise targeted an equal number of respondents from the two tribes for comparison. Because satellite images existed from 1972 (Landsat images), the selection of respondents was based on people over 45 years only to cover the complete period. Thus, all respondents were at least 18 years old in 1989. Abiding by the norms of the two tribes resulted in more males being interviewed than females. The main aim of the study was to examine the relationship between land use and land cover changes and any perceived change in large carnivore populations. The concurrent changes in land-use and cover and population changes in large carnivores were evaluated using chi-squared tests. Chi-squared tests were performed for selected carnivore species (lion, cheetah, leopard, spotted hyena, and African wild dog) to assess differences in the reported trend.

RESULTS

Land use change

The land cover map produced for the two villages had an overall accuracy of 86.5 % and a Kappa statistic value of 0.83 (Table 2). Agriculture, grassland and shrubland were easily discriminated against and therefore exhibited 100.0 % producer accuracy, while woodland was the least discriminated against at 75.0 % (Tab. 2). Over three decades, agricultural expansion in the three closest villages from the SNP border increased by 95% whereas the furthest three villages increased by 90%. Furthermore, forestland decreased by 61% in the three closest villages whereas the furthest three villages decreased by 30%. Grassland for the three closest villages increased by 81% whereas woodland and shrubland decreased by 75% and 30%, respectively. For the case of the furthest three villages, grassland decreased by 47% whereas woodland and shrubland increased by 56% and 38%, respectively (Fig. 3 (a&b) and Table 3). In the three closest villages, the human population increase is proportional to the livestock number (Mbise, 2018).

Table 2. The error matrix for land cover map created for the two villages

Overall classification accuracy = 86.5%. Overall Kappa Coefficient = 0.83					
Class	Validated	Classified	Correct no.	Producer's accuracy	User's accuracy
Agriculture	12	13	12	100.0%	92.3%
Forestland	5	4	4	80.0%	100.0%
Grassland	9	9	9	100.0%	100.0%
Shrubland	7	11	7	100.0%	63.6%
Woodland	4	3	3	75.0%	100.0%
Total	37	40	35		

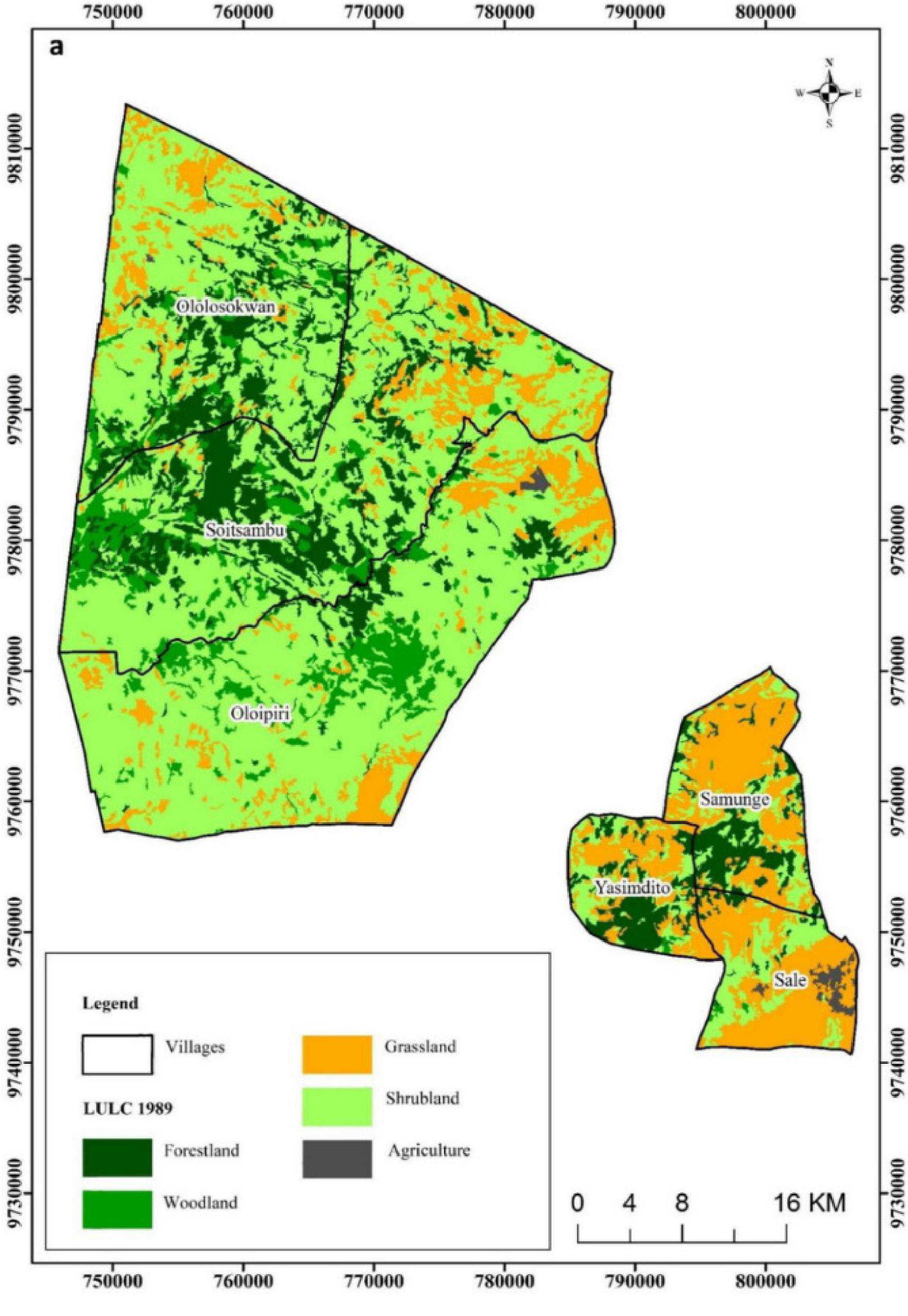

Figure 3a. Baseline satellite image for the two tribal areas in 1989. Raw data was gathered from the United States Geological Survey (USGS)

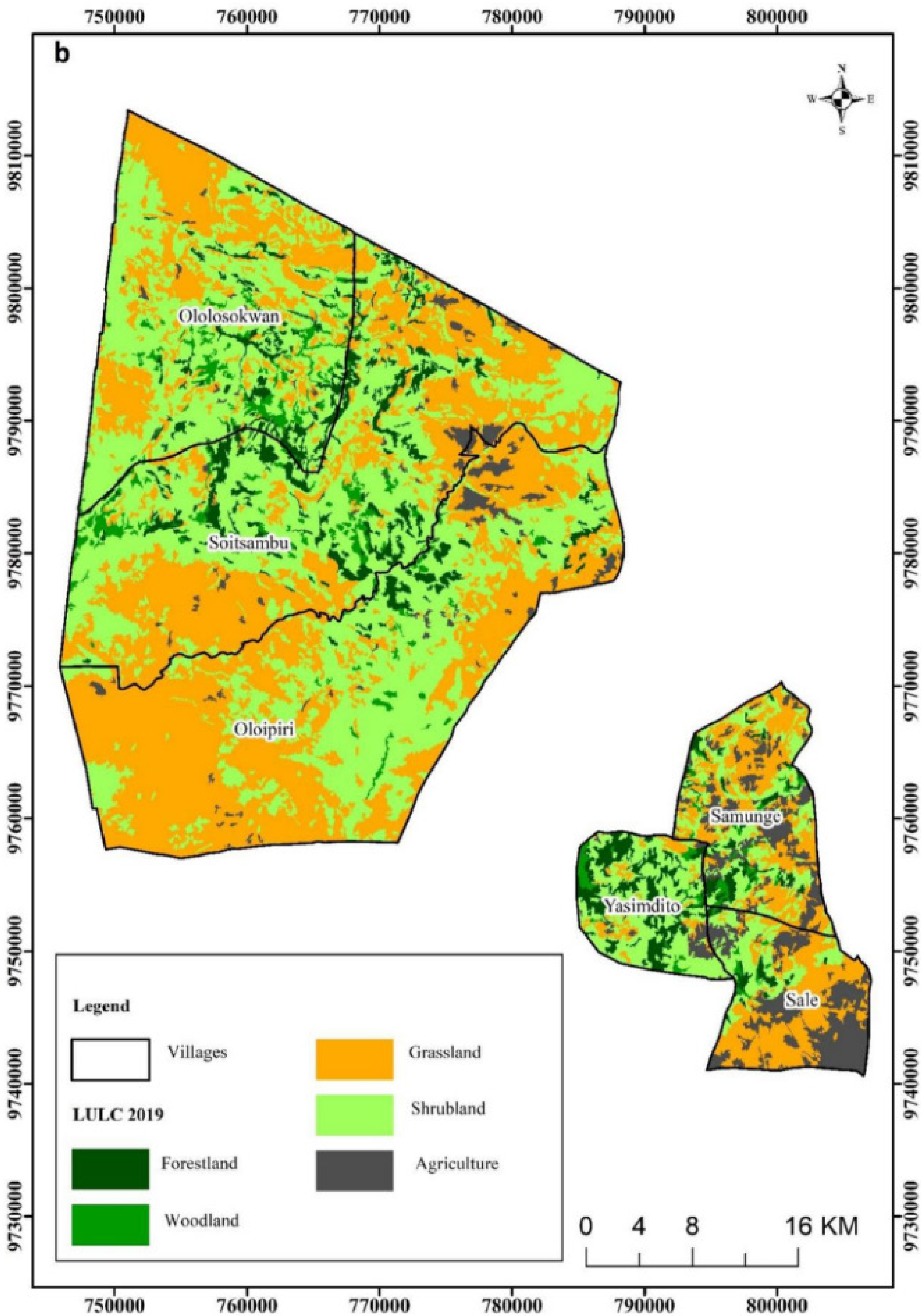

Figure 3b. Baseline satellite image for the two tribal areas after 30 years (2019). Raw data was gathered from the United States Geological Survey (USGS)

Table 3. Land use and land cover (LULC) change (in km^2) across the eastern Serengeti ecosystem during the years 1989 and 2019

	Maasai tribe		Sonjo tribe		Maasai tribe		Sonjo tribe	
	1989		1989		2019		2019	
LULC group	**Area**	**%**	**Area**	**%**	**Area**	**%**	**Area**	**%**
Forestland	236.68	14.7	56.33	15.5	91.23	5.7	39.60	10.9
Woodland	186.53	11.6	5.60	1.5	46.37	2.9	12.28	3.4
Shrubland	1052.25	65.3	73.34	20.2	737.39	45.7	117.63	32.5
Grassland	134.92	8.3	219.66	60.7	705.28	43.7	115.62	31.9
Agriculture	2.03	0.1	7.36	2.1	32.14	2	77.16	21.3
Total area in km²	**1612**	**100**	**362**	**100**	**1612**	**100**	**362**	**100**

Perceived changes in carnivore populations

Most of the respondents reported that the encounter rates of all five carnivore species have declined. The reported declines in the lion, cheetah, spotted hyena, and African wild dogs differed significantly between the two areas (three closest (Maasai tribe) vs. three furthest villages (Sonjo tribe) from SNP border) (lion; Pearson X^2 =17.56, df =1, p <0.001; cheetah; Pearson X^2 =21.24, df =1, p <0.001; spotted hyena; Pearson X^2=15.22, df =2, p <0.001; African wild dog; Pearson X^2 =67.09, df =2, p <0.001; Table 4). Consistently more declines were reported from the furthest three villages than the three closest villages as the former are more populated (people/km^2) and have more croplands per km^2 (Fig. 2 & Table 4). Although the reported decline trend for the leopard was not significantly different between the two areas (leopard; Pearson X^2=2.33, df =1, p =0.127), 73.9% of the respondents reported the species to have declined, indicating large-scale declines for this species.

Table 4. Carnivores population trends between 1989 and 2019

Lion			
Village	Increase	Stable	Decline
Close	0	16	74
Furthest	0	0	90
Total	0	16	164
Cheetah			
Village	Increase	Stable	Decline
Close	0	19	71
Furthest	0	0	90
Total	0	19	161
Leopard			
Village	Increase	Stable	Decline
Close	0	28	62
Furthest	0	19	71
Total	0	47	133
African Wild Dog			
Village	Increase	Stable	Decline
Close	48	32	10
Furthest	5	29	56
Total	53	61	66

Spotted Hyena			
Village	Increase	Stable	Decline
Close	27	20	43
Furthest	7	32	51
Total	34	52	94

DISCUSSION

The human population increase rate in the surveyed villages is 7% annually, which is more than twice the rate overall for Tanzania, and which, ultimately correlates with the high expansion of croplands and a higher amount of livestock in the region (Veldhuis *et al*., 2019). The increased demand for land use in the region negatively affects large carnivore populations (Kija *et al*., 2020). To ensure food security, people are moving to arable lands which were former ranges for large carnivores (Laverty *et al*., 2019; van der Esch *et al*., 2017;). For instance, agricultural expansion in the three closest villages from SNP border increased by 95% whereas the furthest three villages increased by 90%, along with respondents reporting a decline in all species of large carnivores. However, the reported decline trends for the spotted hyena and African wild dog in the three closest villages had a big disparity. This can be caused by the nature of these two species and where the respondent household is located.

Loliondo Game Controlled Area, where both the Maasai and the Sonjo tribes have been residing for many years, used to be a ground for wildlife, and some species like wildebeest (*Connochaetes taurinus*) and zebra (*Equus burchellii*) that are migrating through the Serengeti-Mara ecosystem, and near the villages studied (Mbise, 2022b). However, since people have been allowed to live inside the game controlled area, land cover and land use change have changed the area dramatically (Kija *et al*., 2020;). Species like leopards, which can hardly live side by side with humans, the LGCA forest becomes the only refuge for their survival. For instance, in 1989 the forest cover for the three closest villages was 236.68 km^2, but satellite images from 2019 show that it had decreased by 61%. In addition, the human population increase in the area is proportional to the increase in livestock numbers (Lindsey *et al*., 2017; Maddox, 2003); therefore, grassland area has increased at the expense of forestland, woodland, and shrubland. The expansion of farming activities and keeping large numbers of livestock to sustain livelihoods in the region has had a huge impact on large populations of carnivores. Therefore, the conservation of large carnivores in the area needs management initiatives that support their conservation (Hazzah *et al*., 2017), by addressing the existing problems on the ground caused by high human and livestock populations increase (Mbise, 2018).

The decline of the prey base in Loliondo due to human and livestock population increase has a severe impact on large carnivores' survival (Maddox, 2003). When prey numbers are limited, large carnivores have no options for dietary preferences, therefore the result is increased livestock depredation and ultimately a provoking conflict with livestock owners (Lindsey *et al*., 2017). Thus, managing the prey base is important to reduce the chances of carnivores switching preferences into livestock (Yirga *et al*., 2014). Different species have different adaptations in response to land cover and land use changes (Mbau, 2013). For instance, the leopard and the spotted hyena can live in disturbed habitats despite human activities, however, the African wild dog and cheetah cannot adapt to live in a disturbed habitat (Lindsey *et al*., 2004). Therefore, management measures should be adapted to the need of the carnivore species in question.

Large carnivores populations outside the well-protected Serengeti National Park are facing severe declines due to human activities pressure Veldhuis *et al*., 2019). As a result of these human pressures, habitats are shrinking, and the prey base is declining, resulting in an increased encounter rate between large carnivores and humans, leading to carnivore declines. As hypothesized, the reported decline in large carnivore populations in the surveyed villages is more pronounced in the three furthest villages from the SNP border compared to the three closest villages. The study concludes that; the future of the large carnivores will depend on how LGCA management addresses the existing problems of high human and livestock populations increase, which disturb ecosystem functions in the area. Conservation initiatives of large carnivores in LGCA should thoroughly consider a management approach that discourages the conversion of land to croplands and promotes zero-grazing husbandry.

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Masai Giraffe (*Giraffa tippelskirchii)* population structure and distribution varies across land use and management types in East Africa Savannah

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ABSTRACT

Wild ungulate abundance and distributions are affected by ecosystem variations, management types, and land use. Specifically, giraffe have shown large decline due to habitat loss, fragmentation, and changes in land use affecting distribution and isolated populations. Our goal was to investigate habitat conservation prioritization effects on giraffe population dynamics in a mosaic landscape. Five management regimes were identified across the Tsavo landscape: national parks, community ranches, community conservancies, national reserve, and small-scale agricultural areas. Using road transects, we assessed how the endangered Masai giraffe (Giraffa tippelskirchii) population structure, density, and distribution varied across different land use management regimes. A total 8,181 kilometers were surveyed covering an area of 17,058Km^2. South Kitui National Reserve had no giraffes, while national parks represented 80% of the total sightings. Although herd types did not differ significantly across land uses (p>0.05), group structure varied among all land uses (p<0.05). Lone males and bachelor herds were abundant (37.7%) while females were more abundant (58%) of the total sightings. Adult sex ratios were high in the small-scale farms (0.53 male :1 female) and low in the parks (3.60 male :1female). High mean group sizes of giraffes were recorded in the conservancies all seasons (Dry season: $\bar{X}$= 4.29±0.9 SD and wet season: $\bar{X}$ =6±1.8). All land uses are important to the conservation of giraffes. Giraffes in Tsavo landscape occupy diverse land uses influencing group structure and density. Small scale farms, especially along the corridors, should be developed based on land use plans that favor landscape connectivity. Strengthening ranches management and conservancies to support giraffe populations and support transboundary collaborations will be the key to maintain habitat heterogeneity and giraffe subpopulations.

Keywords: Land use, management, masai giraffes, population structure

INTRODUCTION

Giraffe abundance and distributions vary between landscapes, habitats, and seasons (Okello et. al., 2016). In the last decades, the number of giraffes in Africa has declined by nearly 40% due to a combination of threats like severe poaching, human-wildlife conflicts, habitat fragmentation and loss due to an increase in human population and associated land use changes (East, 1998; Muller et. al., 2016). Land use and management of wildlife habitats affect giraffe distribution and population structure (Bond et al., 2020). Muller (2018) showed that giraffe populations are affected by management types and influenced by the presence of predators in Lake Nakuru National Park by reduction in recruitment. In addition, distribution and structure vary with the risks associated with each land use type (Ihwagi et al., 2015). Increased illegal hunting of giraffes has also shown sex biasness, skewing the population to male sex (Marealle et al., 2010), while proximity to humans affect local social structure in a giraffe metapopulation (Bond et al., 2020). Behavioral changes have been documented in wildlife triggered by anthropogenic activities (Stabach et. al., 2016), while vegetation density has played a key role in the distribution of wild ungulates and influenced by predation risk.

Giraffes are affected by livestock in different ecosystems. Crego et. al., (2020) demonstrated that giraffes avoided areas with high livestock densities. The spatial and temporal impact of livestock on giraffe distribution remain less studied; however, Masiaine et. al. (2020) showed that space use by large mammals was highly affected by the presence of livestock in Loisaba Conservancy, Kenya. Additionally, they indicated that livestock competitively excluded large mammalian herbivores when livestock numbers increased.

In Tsavo landscape comprising of four national parks, one reserve and tens of group ranches, protected areas (under Kenya Wildlife Service (KWS) comprise more than 60% of the total landmass of Taita Taveta county where exclusive conservation is key. Ranches practice livestock production, although wildlife integrates freely with livestock with periodic livestock incursions from Northern Kenya. Small-scale farming is a common practice within the local communities; however, ranching is the key income generating business in the region with more than 33 ranches. In the recent past, the “conservancy model” (KWCA, 2016) has been adopted in some of the ranches although yet to be actualized, but Lualenyi, Mramba and Oza (LUMO) conservancy has been established by three ranches coming together. It is one of the oldest community conservancies in Tsavo Conservation Area (TCA). Other ranches have continued to operate as Directed Agriculture ranches (1% shareholding belongs to the government), individual, family, cooperative, or community ranches. South Kitui National Reserve (SKNR) forms the Northern boundary of the Tsavo Landscape and it is managed by the County Government of Kitui with support from KWS.

Giraffes and other wild ungulates seasonally move through this mosaic landscape to refuges in the Tsavo West, Tsavo East National Parks in Kenya, and Mkomazi National Park in Tanzania. The effects of anthropogenic activities, land uses, and variations in the management of habitats on giraffe populations have not been well understood in Tsavo landscape. In this study, we used giraffe road counts to determine Masai giraffe population density variation, structure, and distribution between five sets of land use practices within Tsavo Conservation area under various management regimes. We predicted that parks would have high giraffe density and high recruitment rates due to increased protected and size of the protected areas while small scale farms would have low population densities with an age structure similar in all land uses. The study will provide information that will be used in directing resources in protecting, conserving, and management of habitat priority areas for giraffes and other large mammals in Tsavo Mkomazi Landscape.

MATERIALS AND METHODS

Study area

This study was conducted within Tsavo Conservation Area (TCA) which covers approximately 42,000km^2 in southern eastern Kenya, located 1^{0}4'to 3^{0}55' south and 37^{0}04' to 39^{0}43' east (Figure 1). TCA is located 250km south of Nairobi and incorporates 3 national parks - Tsavo West (TWNP), Tsavo East (TENP), and Chyulu Hills (CHNP). South Kitui National Reserve (in Kitui County) adjacent to TENP is also considered part of the TCA. Ranches and conservancies form dispersal and migratory corridors for wildlife within the Tsavo-Mkomazi Landscape which extends to Northern Tanzania. Rainfall is erratic, ranging from 250mm to 500mm annually (Leuthold & Leuthold, 1975) varying depending on the altitudes which ranges between 200 and 1000 meters above sea level. The vegetation is characterized by semi-arid bushland and Acacia- Savannah woodland and is home to over 30% of the total Masai giraffes in Kenya (Waweru et al., 2021)

Nomadic pastoralism and sedentary livestock integrated with small-scale farming surrounds the entire study area. Areas adjacent to TENP are semi-arid with surrounding communities practicing pastoralism. On the other hand, ranches mainly practice livestock production with some venturing, into conservation, tourism, mining, and carbon offsetting.

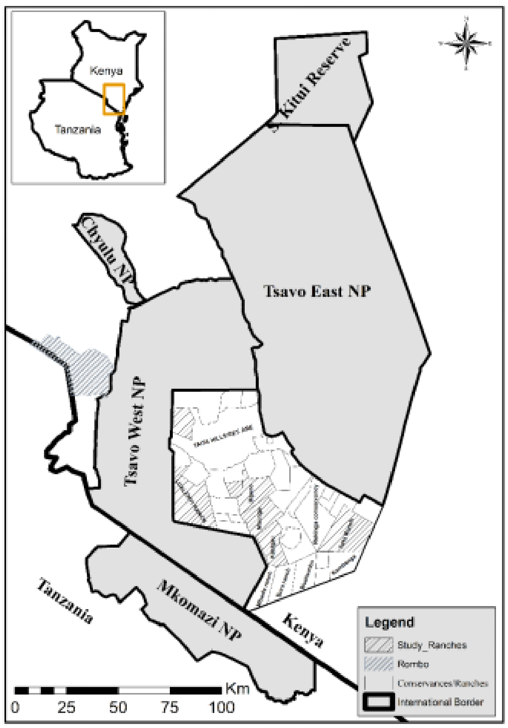

Figure 1. Map showing Tsavo Conservation Area with the study areas based on land uses

Land use classification

Land use has been defined as patterns of human activities such as agriculture, forestry, and building construction that alter land surface processes including biogeochemistry, hydrology, and biodiversity (Ellis, 2010). We classified land use into five distinct categories based on management and the main practices in areas where giraffes occurred. Key land use activities included exclusive conservation and tourism (parks, 62% of Taita Taveta county), ranching (livestock production and wildlife, over 1million acres (TTWCA, 2021), community conservancy (communally owned and managed conservancy where human activities are restricted), reserve (a county government owned and managed conservation area with controlled utilization (http://www.kws.go.ke/content/overview-0), and small-scale agriculture areas (Table 1). Small scale agriculture is practiced within the pockets of Taita Taveta county such as Wundanyi, Kasigau, and Njukini in the East and Western side of Tsavo West National Park. Sisal plantations in Mwatate and large-scale livestock production take significant areas within the county.

Existing road networks within the ranch and parks were used to design the road transects considering the vegetation types in different management types. The management types were derived from the ownership and operations of the land as per Table 1 above.

49 transects were resampled seven times, covering a total of 8,181 kms including Tsavo West and Tsavo East National Parks, South Kitui National Reserve, 4 ranches (Mgeno, Maungu, Kasigau, Taita ranches), 1 conservancy (Lumo community conservancy), and one small-scale agriculture area (Rombo group ranch). Three observers driving at a speed of 20 km/hour conducted the surveys between 0600hrs and 1000hrs when the animals were active. Once a giraffe or group of giraffes was sighted, GPS coordinates, distance and angles to the center of the group, group type, sex, and age class of the giraffes were recorded. Age was classified in three categories based on physical characteristics, body shape, relative length of the neck and legs, and ossicone characteristics (Strauss, 2014; Muller, 2018): adults (> 3 years for females and > 6 years for males), sub-adults (1-3 years), and juveniles (< 1 year). Sex was differentiated through morphological characteristics (Muller, 2018). Age class and sex were recorded as unknown if it was not possible to identify the given individual in the group (e.g., sex of calves and subadults). Groups were categorized as: lone males and bachelor herd (a group of 2 or more sub-adult and adult males), mothers with calves (females with young), mixed herd (males and females) and lone females. Giraffe sightings beyond one kilometer were not included and individuals found within a radius of 500 meters were considered the same family group. Data were collected seasonally after every 4 months from May 2019 to August 2021. To account for seasonality, we classified wet and dry with a wet season ranging from October to April and a dry season from May to September.

Table 1: Land use and management type

Land use	Management type	Site(s)	Size
Exclusive Conservation and tourism	Government of Kenya through KWS	Tsavo West, Tsavo East and Chyulu National parks[1].	22,812 km^2
Community conservation area (wildlife and tourism)	Community shareholding company	LUMO community wildlife conservancy	4,800 km^2
Ranching (livestock and wildlife)	Community shareholding companies	Maungu, Kasigau, Taita[2], Mgeno ranches	25,447 km^2
Reserves (conservation)	County government of Kitui	South Kitui National Reserve	1,833 km^2
Small scale farms (farming and pastoralism)	Community/individual farms	Rombo group ranch area	9,500 km^2

Data analysis

We inputted, collated, stored, and processed the collected data in Microsoft Excel. For comparing the population demographic variables (age and sex) of giraffes in land use (parks, community conservancy, reserve, small scale farms, and ranching), a chi-square and ANOVA test was used. Demographic variables analyzed included group size and group type, reproductive ratio (calculated as the number of calves per adult female (juvenile: adult female), sex ratio (Male: Female), detection and density. To test the differences between giraffe age groups, the individuals were grouped into adults, sub-adults, and juveniles per land use.

We calculated giraffe densities as; a) kilometric detection where detections were calculated as the number of giraffe sightings observed per distance covered (detection probability) in all land uses, b) giraffe density per area using the formula Density: D=N/2LW, where D=estimated density of animals in each land use, N=number of sightings, L=length of transect lines, and W=mean perpendicular distance of animals seen (Thomas et al., 2010). Further analysis to test the density difference between land uses was done using Kruskal Wallis test in R program.

RESULTS

Group size and group type

Across all seven rounds of surveys, we sighted giraffes in 625 occasions. We did not record any giraffes in South Kitui National Reserve. 590 sightings were grouped into various group types. Bachelor herds and 'lone males' accounted for 37.7% (n=224) of the grouped sightings (n = 590) while 'lone females' were least sighted (12%; n=72). Mixed herds accounted for 24% (n=142) of the total grouped sightings, while 26.7% were 'families' (mothers and calves; n = 152). Group types did not differ significantly across land uses (x^2= 14.7, df = 9, p>0.05, figure 2). Although the parks had relatively large herd sizes, the mean herd sizes did not vary across different land uses (x^2= 0.22, df = 4, p>0.05; Figure 3).Figure 2: Frequency of sightings of different group types in the study area. Giraffe group sizes in parks and ranches had low deviations from the mean compared to conservancies and small-scale farms throughout the season (Figures 4 and 5). Conservancies and agricultural farms had high deviations during the wet season ($\bar{x}$=6 ± 4.8 and $\bar{x}$ =4.8 ± 4.2). A post hoc analysis showed that giraffe mean herd sizes varied with seasonality between land use ($p<0.05$), with small-scale farms and conservancies showing increased variance.

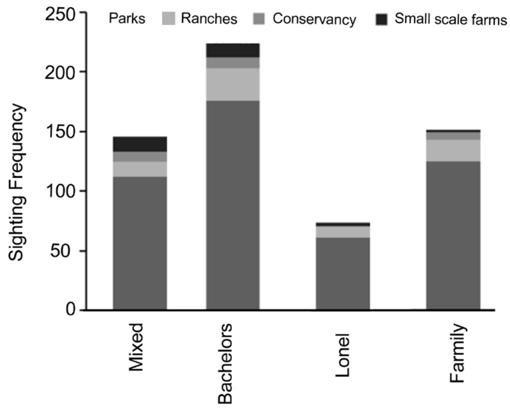

Figure 2: Frequency of sightings of different group types in the study area

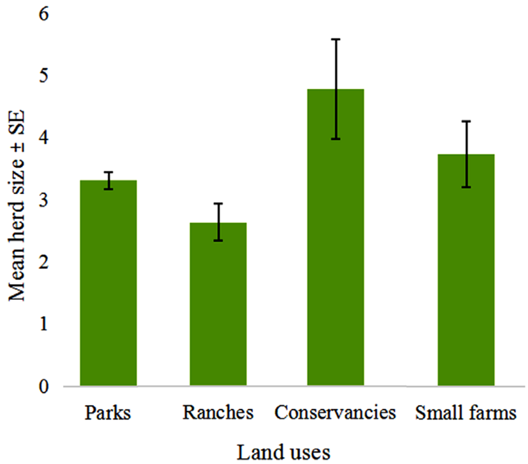

Figure 3. Giraffe mean herd sizes in various land uses Error bars represent standard error

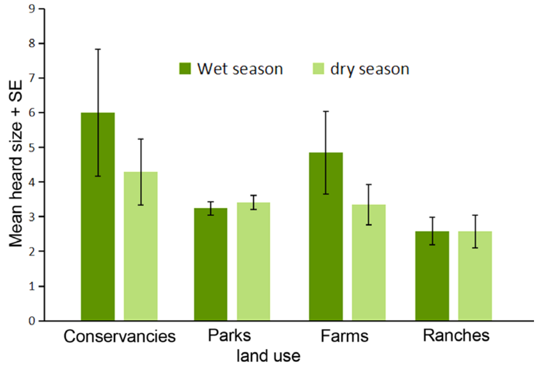

Figure 4. Mean giraffe herd size in dry season and wet season in different land uses in TCA

Sex and reproductive ratios

Parks and ranches had a 1:2 sex ratio each, while conservancies and small-scale farms had a ratio of 1:1.43 and 1:0.78, respectively (Table 2). Parks had the lowest reproductive ratio (3.60:1) while small-scale farms had the highest reproductive ratio (0.53:1).

Age Groups (Adults, Subadults, Juveniles)

87% of the total counted giraffes (N=2,082) were positively sexed while 264 individuals were not sexed. There was a significant difference between age structure in all the land uses (x^2=39.9, df =12, $p < 0.05$). The parks had higher individuals of all categories, while in small-scale farms males exceeded the number of females sighted whereby 46% of the total giraffes observed while females comprised 26%.

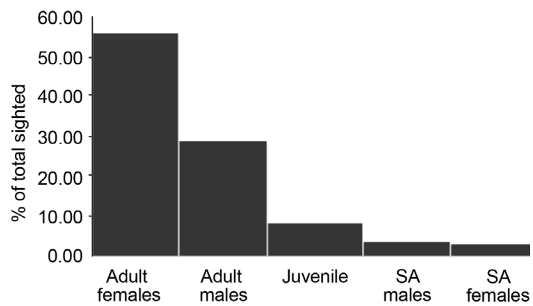

Figure 5: Age group distribution

Table 2. Sex and Reproductive ratios of Giraffes in TCA

Land Use Type	Sex Ratios (Male/ Female)		Reproductive Ratio (Juvenile/Adult Female	
Area	Male	Female	Juvenile	Adult female
Parks	1.00	2.08	1	3.60
Ranches	1.00	2.15	1	2.10
Conservancies	1.00	1.43	1	2.36
Small-scale farming	1.00	0.78	1	0.53

Transect Detection

In total, 8,180 kilometers were covered; Six thousand five hundred and forty kilometers in the parks, ranches 1,111 km, small scale farms 191 km, and conservancies 339 km. Pearson correlation showed a strong correlation (r=0.9) between distance and number of giraffe's sightings. High detections were recorded in small-scale farms (mean= 0.81, SE=0.71), while ranches had the lowest detections (mean=0.14, SE=0.04). 80% of the total detections were recorded in parks, 11% in ranches, 4% in conservancies, and 4% small-scale farms (Fig. 6). The detections did not differ significantly across land uses and between seasons (x^2= 4.09, df = 3, p>0.05).

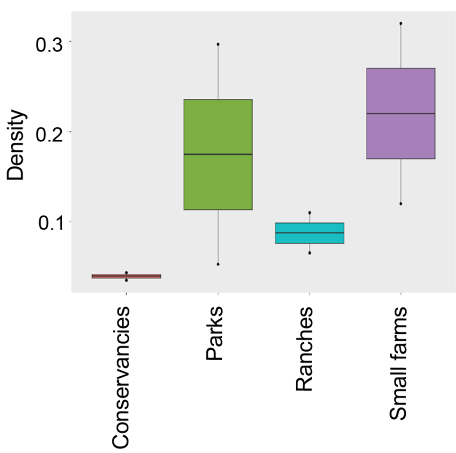

Figure 6. Giraffe detection per Kilometer under different land uses in TCA

Giraffe Population Densities

There was no significant difference in giraffe density across the land uses (x^2= 5.1667, df = 3, p >0.05) and in all seasons. Overall, small-scale farms had higher densities of giraffes ($\bar{X}$ = 0.220 ± 0.1) while conservancies had the lowest densities ($\bar{X}$ =0.039 ± 0.004), (figure 7).

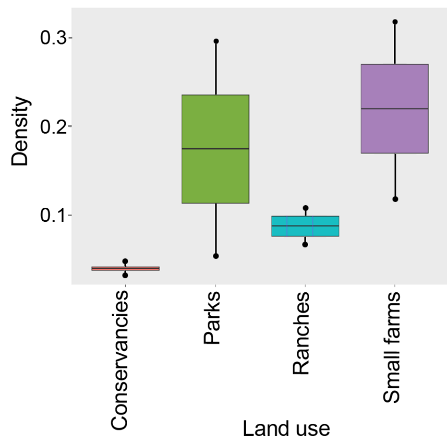

Figure 7. Giraffe density under different Land uses in TCA

DISCUSSION

To conserve viable giraffe populations within the Tsavo-Mkomazi landscape, critical considerations should be given to the entire population range. Although our assumption was that the populations are independent, the fluidity within the landscape is evident specifically due to contagious nature of the landscape hence the importance of the corridors in connecting key conservation areas. All land uses remained important to giraffes at different seasons. We analyzed a heterogenous population of giraffes in the Tsavo Conservation Area and considered them as subpopulations based on land use and management of the habitat they are occurring in. We hypothesized that giraffes in parks have higher densities, high recruitment rates, and age structure and family composition will be the same in all land uses.

Group size and type

Although group types did not differ significantly across land uses, age structure, mean group sizes, and group composition differed significantly between seasons. Bachelor herd sightings were dominant in all land uses except in small-scale farms where mixed herds were dominant. Although female giraffes have stronger social associations than males, Ferres et al., (2021) found that males are more socially connected, which may explain our finding of bachelor dominance in most of the land uses. Bond et al., (2021) showed that giraffes' proximity to humans appeared to play a potentially important role in mediating the patterns of social associations between female giraffes in northern Tanzania. This could have led to grouping and regrouping of families in agricultural dominated habitats and in conservancies where tourism is dominant. This regrouping and grouping of giraffes varied between seasons and we recommend further studies on the underlying factors behind group composition to provide better information hence management of those populations in human dominated areas.

Sex and reproductive ratios

Higher sex ratios were recorded in ranches and parks, while low ratios were recorded in small-scale farms. Ranches had higher sex ratios than the conservancies. The highest reproductive ratio was recorded in small-scale farms. Contrary to our hypothesis, parks had the lowest reproductive ratios. Sex ratio variances have been attributed to various genetical and environmental factors (Szekely, 2014) and have an impact on giraffe population. Jennions et al., (2017) argued that if males become more common in the population, the population's reproductive success will decline due to the Fisher condition. Bond et al., (2020) observed similar results among subpopulations adjacent to Lake Manyara National Park. Low reproductive ratios in the parks could be attributed to predation vulnerability of the young (Wilfred, 2010) and high population specifically in Tsavo West skewing the results. These findings concur with Muller (2019) where lions affected the population structure of giraffes in Lake Nakuru National Park. High reproductive ratios in small-scale farms were due to low populations.

Age structure

Age structure differed significantly across land uses. Only in small-scale agricultural areas, adult males exceeded the number of adult females sighted. Although giraffe sex differed across land uses, there was a significant difference between all land uses and small-scale farms. More young ones were recorded in the park with low densities. This could be attributed to the seasonality of calving and largely influenced by vegetation types and water. Tsavo West National Park has permanent water sources within the western side with acacia vegetation extending to Rombo areas of small-scale farms. As giraffes prefer acacia species (Anyango et al., 2013), there could be a high preference on the western side of the park and Rombo where vegetation is favorable and water is in plenty.

Detection and Density

High detections per kilometer were recorded in small scale farms. Parks, ranches, and conservancy detections per kilometer did not differ statistically. The detections are contrary to our prediction that small-scale farms would have few giraffe detections per kilometer compared to other land uses. Combined ranches, conservancies, and small-scale farms host 20% of the total giraffe detection while parks had 80%. Although ranches and conservancies had equal detection (4%), the area covered differed significantly. Ranches are predominantly livestock dominated. A post hoc analysis showed that giraffe mean herd sizes varied with seasonality between the land use ($p < 0.05$). Whereas livestock have shown to influence large mammal detection (Masaine et al., 2020), cause a temporal shift of time in resource use by wildlife (Conolly et al., 2020), the specific spatial and temporal responses of giraffes are less understood. Our data suggests that high giraffes' detections do not really indicate population viability.

Although detections were not significantly different between the land uses, high deviations were recorded in the wet season by conservancies and small-scale farms. This can be attributed to its proximity to Tsavo West National Park. Giraffes could be safer in the park or had little disturbance from anthropogenic activities. These results concur with Okello et al. (2015) where cross-border giraffe populations changed with season. Densities did not show any variations in parks and ranches across the land uses, which may indicate that the populations are independent except for small-scale farms and conservancies.

Land use and management types

Small scale farms had higher densities of giraffes although the structure varied with males being more than females. The situation can be ascribed to habitat size, poaching (unpublished data), habitat preference, and habitat loss due to agriculture expansion and the associated risks. Effects of land use and management types in relation to giraffe conservation remain less studied. Ihwagi et al., (2015) observed variance in elephants' populations and movement varied significantly based on the risks and associated with each land use and management type in Laikipia. Similarly, Crego et al., (2020b) showed that seasonal increment of livestock affects wildlife detection in ranches and caused spatial variations. Post hoc analysis showed that giraffe mean density varied with season with higher variances recorded in small-scale farms and conservancies. Amara et al., (2020) showed that the high numbers of livestock in ranches contribute to the low above-ground biomass in LUMO and adjacent areas. Poaching/illegal hunting has been documented to alter giraffe populations (Marealle et al., 2010). Our results agree with those of Bond et al., (2021), where giraffes closer to human settlements had higher reproductive rates.

Although we did not examine the survival rates within the agricultural dominated areas, and the higher male ratio, land use, and poaching can be used to assess survival. Lee (2018) observed increased survival and growth rates of giraffes in Burunge Wildlife Management Area after the area was changed to conservation and tourism. The impact of different management types of land on giraffes remains less understood; however, land ownership and use with different objectives have shown to have an impact on wild ungulates. Non-protected areas in Kenya host significant populations of wildlife (Ogutu et al., 2016). These non-protected areas fall under different management regimes ranging from cattle ranching to pure conservation and integration of the two. Although Crego et al., (2020b), showed variations and fluctuations in detection between different land uses and management in Laikipia, the usage of such land uses by wildlife has been varying seasonally and with associated risks such as predation and poaching (Ihwagi et al., 2015), productivity (Ogutu et al., 2016) and threats (Stabach et al., 2016). Although with low densities, parks and ranches hold stable fluctuations which did not differ with season. These scenarios could be interpreted in two ways, either the two habitats are safe for giraffes or the management and land use is compatible with giraffes' ecological demands.

CONCLUSIONS

The current changes in land use, increased fragmentation of habitat, and poaching threaten the survival of giraffes in Tsavo-Mkomazi landscape. Historical records (Omondi and Bitok 2005, Omondi et al., 2008) indicate giraffes' presence in South Kitui National Reserve, however, increased human activities, charcoal production, livestock and poaching could have driven the population to extinction or dispersal from the reserve. The current composition of giraffes in small-scale farms indicates an threatened populations confined by anthropogenic activities. Sex ratios are skewed to males, coupled with agricultural expansion and increased poaching may lead to local extinction along the corridors. Our data indicate a possible sedentary giraffe population in the ranches as there was no major variations in both density and detections, measures to protect this population should be enhanced as poaching in the ranches and corridors remain rampant. Since large populations of wildlife reside outside protected areas (Ogutu et al., 2016), ranches and community conservancies are vital in wildlife conservation. Equal prioritization should be given to ranches and conservancies with critical emphasis on corridors to ensure landscape connectivity and habitat heterogeneity.

We support the recommendations of (Ojwang et al., 2017) on the development and gazettement of participatory land use plans, strengthening the transboundary collaborations and security enhancement as a partial solution to enhance the protection of giraffe corridors within Tsavo Conservation area in the larger Tsavo-Mkomazi Landscape.

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WILD MAMMAL ROADKILL IN THE SERENGETI ECOSYSTEM, NORTHERN TANZANIA

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ABSTRACT

Roads affect wildlife in many ways, with roadkill probably the most conspicuous and the main threats to wild mammal species conservation worldwide. Globally, wild mammal roadkill have been reported to occur in different protected areas but very little information on the problem is available in the Serengeti ecosystem. This study employed both cross sectional observation and opportunistic encounter methods to determine the patterns of wild mammal roadkill of different body sizes along the existing gravel road networks in the area. The results indicated that 29 wild mammals with encounter rates of 0.0156 animals /kilometer grouped as herbivores (75.9%), carnivores (13.8%) and omnivores (10.3%) were recorded killed. Wild mammals with small body sizes (<10.0Kg, 44.8%) represented by the African hares (Lepus capensis, 31.0%) were most frequently killed in the area. Moreover, wild mammal roadkill was significantly higher during the dry (52.6%) season because probably the season is linked to their mating season, when individuals tend to move more frequently or longer distances to find a mate and forage resources thus increased their chances of being hit by vehicles. In addition, wild mammal roadkill occurred most frequently during the morning (50.3%) hours and on good roads (75.0%) probably because of the over speeding behavior by drivers as they are attracted to drive fast on such roads. The study findings recommends for adopting traffic management measures to mitigate mammalian roadkill in the Serengeti ecosystem.

Keywords: small to large body-size, conservation, wild mammals, roadkill, Serengeti ecosystem

INTRODUCTION

Roads traversing protected areas are known to cause mortality of animals due to accidents and with vehicles traffic, road construction or maintenance in some cases causes habitat loss due to deforestation (Andrews, 1990, Bennett, 1991, Forman and Alexander, 1998). Presence of accessible and well-maintained roads in protected areas influence higher tourist activities hence increases the human impact on fauna per area (Barthelmess and

Brooks, 2010). However, few reports has focused on one area of particular concern that is wildlife-vehicle collisions (Brazand Franc, 2016). According to Meza-Joya et al. (2019), wildlife-vehicle collisions are acknowledged as the leading source of vertebrate's mortality worldwide. Also, it had been previously found that roadkill has the potential to drive threatened mammalian populations to extinct (Cook and Blumstein, 2013). This is in support of the study by Barthelmess and Brooks (2010), who reported that collisions are the primary cause of death for moose (Alcesalces) in most of the protected areas in temperate climate and in the Kenai National Wildlife Refuge in Alaska. Another incidence of vehicle collision as reported by Barthelmess and Brooks (2010) that badgers was mostly killed in England and also death for Iberian lynx (Felis pardina) recorded the second in Spain. Therefore, wildlife roadkill the greatest anthropogenic source of direct mortality for vertebrate's mammalian species on Earth (Meza-Joya et al., 2019).

Several studies on roadkill in Tanzania presented the occurrence of dead animals on the roads (Kioko et al., 2015a; Kioko et al., 2015b; Lyamuya et al., 2016; Njovu et al., 2019; Nkwabi et al., 2018), however, they have not indicated the effect of body sizes on the exposure to roadkill. In order to determine mortality on wildlife population caused by vehicles roadkill counts have been used across seasons and years in protected areas (Beheraand Borah, 2010; Brazand Franc, 2016).

Therefore, this study aimed at bridging this gap by documenting wild mammal roadkill of different body sizes and compares those patterns between different wild mammal species in the Serengeti ecosystem. Study by Ford and Fahrig (2007) reported body size and diet preference are important variables to explore patterns in interspecies variation in roadkill frequency and how does it affect the probability of roadkill. This study hypothesized that wild mammalian herbivores occur at higher population densities and hence could have a higher roadkill frequency than omnivores and carnivores. Secondly, small sized wild mammals (<10.0 kg) would be killed more often than expected because of their abundance in the Serengeti ecosystem. Thirdly, wild mammal roadkill would be frequently occurring during the dry than wet season because the dry season is linked to higher influx of tourist activities and traffic volume in larger areas of the area.

MATERIALS AND METHODS

Study area

The study was conducted in the northern part of Serengeti ecosystem specifically in main gravel roads of Serengeti National Park (SENAPA) and Ngorongoro Conservation Area (NCA) in northern Tanzania (Fig.1). The ecosystem has about 70 mammal species (McNaughton, 1985; Sinclair and Arcese, 1995) and more than 600 avifauna species (Nkwabi et al., 2018), and supports one of the largest herds of migrating ungulates and the highest concentrations of large predators in the world (Sinclair et al., 2015). High diversity 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 is 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 receives bimodal rainfall, short (November-December) and long (March-May) seasons. However, in some years inter-annual variations are inevitable especially due to climate variability. The woodland area is occasionally interspersed with patches of tall open grasslands and receives an annual maximum rainfall of 1100 mm (Norton-Griffiths et al., 1975). In general, the Serengeti woodlands are mainly composed of *Vachellia, Balanites* and *Commiphora* species with broad leaved species such as *Terminalia*, *Euclea* and *Croton* as sub-dominates (Bukombe et al., 2018). The woodlands are dominated by the intermediate grasslands and woodlands. The topography is highly variable, with catena effects having important influences on woody species.

Data collection

The survey were conducted during the wet (March-April) and dry (July-August) seasons of 2015 to investigate wild mammal roadkill. One transect was surveyed in one day, morning session (7:30 - 11:30 am) and afternoon session (14:00 to - 18:00 pm). The survey was accomplished along five transects, each with a length of 40 km and included the main gravel roads, namely Naabi - Olduvai, Seronera - Naabi, Seronera - Fortikoma, Seronera - Ndabaka and Seronera - Lobo (Fig. 1). Each of the five surveyed transects covered 40 km in length and was

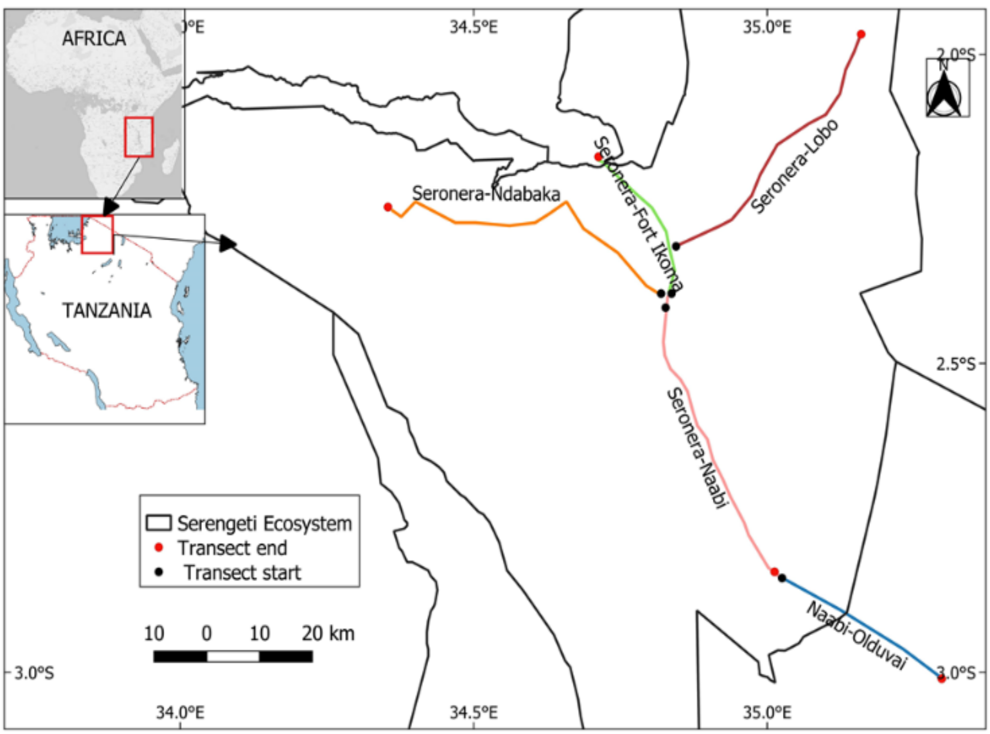

Figure 1. Map of the Serengeti ecosystem showing our study area and transects along the main roads

driven twice a day (morning & afternoon hours). In addition, each transect was driven four times, two times during dry and two times during wet season. All this gave a total of 1600 driven transect km. In this survey, it was assumed that each kilometer of road surveyed was independent from each other; e.g. a 40 km road surveyed twice has equal sampling effort to an 80 km road surveyed once. At the beginning of transect, the vehicle odometer was set to zero and transect name was recorded, as well as GPS location, time, transect length, road width, date, season and names of recorders. The vehicle was driven at 20 kph or less with stops to take records of each mammal or group of animals encountered as recommended by Collinson et al. (2014) and Teixeira et al. (2013).

Each encountered carcass or injured animal species was firstly identified, and the GPS location was recorded. Also, the road width at the sight of the kill was measured using a tape measure. Additional information including time, condition of carcass/injured animal(s), number, estimated age class (adults, sub adults, juveniles), road condition (good = no big hole, poor = several big holes and very rough) sex (male, female) and habitat type (grassland, woodland, wooded grassland, bushland), were all recorded in a standard datasheet. Moreover, when the observers spotted any car coming towards the team, they recorded its speed (Km/hr) by the use of speed gun device and type of vehicle as private, tourist, public or government. Moreover, opportunistic encounter method was employed to record wild mammal roadkill data out of the survey periods but within the study transects. In this method, all mammal species found killed on the transects were identified and recorded at species level, age class, sex, habitat type and their GPS locations were marked. After collecting all required data, the carcass was removed from the road to avoid double counting.

DATA ANALYSES

Chi-square goodness of fit test was used to compare among three dietary category mammals (i.e. herbivores, carnivores, omnivores) and body sizes (i.e. small, medium, large) differences in mammalian roadkill frequency and to investigate on variations based on the taxonomic group. Also, a paired t-test was used to test for if there were any significant differences between mammalian roadkill with season (dry, wet) and session (morning, afternoon) in the area. Furthermore, to evaluate which mammals' dietary category as a dependent variable was mostly frequently found killed in relation to mammal species, mammal order, mammal family, mammal body size, session, season, vehicle speed, vehicle category, habitat type and road width as independent variables we conducted a linear regression analysis with the method enter to evaluate the relationship between tested variables.All tests reported at level of $P < 0.05$ were considered statistically significant. All statistics were done using Statistical Package for Social Science (SPSS, version 16.0) software.

RESULTS

Twenty nine (29) individual species (ranging from 1 to 2 individuals) occurring at a rate of 1.56 individual mammal per 80km belonging to 13 mammalian species from 7 mammalian orders (Table 1) were recorded knocked by vehicles in the area.

Table 1. Mammal species found killed along roads between wet and dry seasons in 2015 in the Serengeti ecosystem

Common name	**Family**	**Scientific name**	**Diet**	**Body mass**	**Total killed**	**% killed**
Thomson gazelles	Bovidae	*Eudorcas thomsonii*	H	M	8	27.6
African hares	Leporidae	*Lepus capensis*	H	S	9	31.0
Black backed jackals	Canidae	*Canis mesomelas*	C	S	1	3.4
Bat eared fox	Canidae	*Otocyon megalotis*	C	S	1	3.4
Spotted hyaenas	Canidae	*Crocuta crocuta*	C	L	1	3.4
Dikdik	Bovidae	*Madoqua kirkii*	H	S	1	3.4
Wildebeests	Bovidae	*Connochaetes taurinus*	H	L	2	6.9
Zebra	Equidae	*Equus burchelli*	H	L	1	3.4
Cheetah	Canidae	*Acinonyx jubatus*	C	L	1	3.4
Olive baboon	Cercopithecidae	*Papio anubis*	O	M	1	3.4
Warthog	Suidae	*Phacochoerus africanus*	H	L	1	3.4
Squirrels	Sciuridae	*Sciurus carolinensis*	O	S	1	3.4
Crested porcupine	Hystricidae	*Hystrix cristata*	O	M	1	3.4
Total					**29**	**100**

Diet (H = herbivore, C= carnivore, O = omnivore) and body mass (S = <10.0 kg, M = 10.0 - 20.0 kg, L = >20.0 kg) were determined from Barthelmess & Brooks (2010).

Moreover, wild mammal species found killed belong to different orders with more individual mammal's species belonged to the order artiodactyla (n = 11, 37.9%) represented by the Thomson gazelles (n = 8, 27.6%), followed by the order lagomorpha (n = 9, 31.0%) represented by African hares (n = 9, 31.0%). Compared to other orders the differences were statistically significant (X^2= 1.74, df = 72, p < 0.001). Furthermore, mammals' roadkill differed significantly between families (X^2 = 2.030, df = 84, p < 0.001) with more individuals coming from the bovidea family (n = 11, 37.9%) followed by the leporidae (n = 9, 31.0%), carnidae (n = 4, 13.8%), sciuridae (n = 1, 3.4%), cercopithecidae (n = 1, 3.4%), suidae (n = 1, 3.4%), equidae (n = 1, 3.4%) and hystricidae (n = 1, 3.4%) families (Table 1).

Wild mammal's species found killed differed significantly in their body size (X^2 = 58, df = 24, p < 0.001), with more records of small body sized mammals (<10.0 Kgs, n = 13, 44.8%) followed by medium (10.0 – 20.0 Kgs, n = 10, 34.5%) and large (>20.0 Kgs, n = 6, 20.7%) bodied sized mammals. However, the African hares (n = 9, 31.0 %) on small body size and Thomson gazelles (n = 8, 27.6 %) on medium body sizes mammals were more frequently recorded killed than other mammals' species in the area.

Wild mammal roadkill was significantly higher during the dry season (52.6%) than wet season (47.4%) (paired t-test, t = 3.664, df = 24, p = 0.001) and during the morning (50.3%) and afternoon (49.7%) hours (paired t-test, $t = 4.123$, $df = 24$, $p < 0.001$). Also, wild mammal roadkill occurred frequently on good roads (75.0%) than poor roads (25.0%) though their differences were not statistically significant ($p = 0.272$) probably because of the over speeding by drivers as they are attracted to drive fast on such roads. In addition, wild mammal species found killed differed significantly among their dietary type ($X^2 = 58$, $df = 24$, $p < 0.001$), whereby herbivores were more killed along the roads ($n = 22$, 75.9%) followed by carnivores ($n = 4$, 13.8%) and omnivores ($n = 3$, 10.3%).

A linear regression model with wild mammals' dietary types (herbivores, carnivores, omnivores) as a dependent variable and mammal species, mammal order, mammal family, mammal body size, session, season, vehicle speed, vehicle category, habitat type and road width as independent variables indicated a significant difference across the dietary groups was statistically significant ($F = 6.10$, $df = 10$, $P < 0.001$, $r^2 = 0.813$). However, wild mammal species was the only significant independent variable in explaining the observed variation ($t = 3.15$, $p = 0.010$).

DISCUSSION

This study accounts for 29 wild mammal roadkill belonging to 13 species, 7 orders and 8 families in the northern Serengeti. This finding is in line with previous work which revealed that thousands of wild mammals were killed annually from vehicle collisions, making the issue an important one for conservation biologists and environmental managers (Smith-Patten and Patten, 2008). The study findings also corroborate with that of Canova and Balestrieri (2018), who pointed out that 40 – 50% of wild animals are killed on roads each year, and thus supporting that road casualties currently being the main direct human cause of mortality for many species. Previous study (Bukombe et al., 2018), have also revealed that roads and traffic impact wildlife negatively by decreasing habitat quality through, facilitating the introduction and spread of exotic species. Roads also act as barriers to genetic exchange hence reducing genetic diversity, subdividing animal populations, promoting meta population extinction, and increasing wildlife mortality due to wildlife-vehicle collisions (Meza-Joya et al., 2019).

Herbivores were the most affected group (75.9%), followed by carnivores (13.8%) and omnivores (10.3%) in the area. In support of our first prediction that mammalian herbivores have a higher roadkill frequency than carnivores or omnivores and concurs with findings by Canova and Balestrieri (2018). The reason for the higher herbivore mammalian roadkill was probably the fact that more herbivores mammals' species have large home ranges and occur at higher densities (Green-Barber and Old, 2019), and are attracted by grasses along the roadsides (Freitas et al., 2015). Furthermore, the wild mammalian herbivores are attracted to road sides by resources that are rare or limited in other areas, including water and green pasture as source of food (Green-Barber and Old, 2019) and therefore increase chances of being hit by vehicles. According to Kiros et al. (2016), wild herbivores come out and cross highways while seeking for food and water.

We also found that, the African hares which are small body mammal size were more recorded killed than medium and large body size mammal species probably because they are abundant species (Caceres, 2011) and their behavior of frequently crossing roads to gain access to other resources (Green-Barber and Old, 2019). In addition, since the African hare are nocturnal, they might have been hit by vehicles more frequently at night or early morning because of the reduced driver vision (Brazand Franc, 2016), which may shorten the time a driver has to react to an animal on the road, and the proportion of animals active at night (Chyn et al. 2019). Therefore, this finding supports our second hypothesis that small sized wild mammals (<10.0 kg) would be killed more often than expected because of their frequency of crossing the roads and being abundant in the area (Barthelmess and Brooks, 2010). This finding is in line with that of Gonzalez-Suarez et al. (2018) who pointed out that species weighs above 2-3 kgs had higher risk of being killed, although for wild mammals the risk decreased again for species above ~50 kgs due to the reason that drivers can see them at a distance and slow down vehicle.

In this study, predators and scavengers such as bat eared fox, spotted hyena, black backed jackals and cheetahs were recorded in the area. This finding is consistent with that of the previous study by Freitas et al. (2015), who suggested that the African hare were frequently hit by vehicles because of their attraction to road edges and therefore increasing their risk of roadkill and that of their predators or scavengers. Also, it supports the study by Planillo et al. (2018) which reported that landscape disturbance by roads may increase abundance of prey in verges (i.e., strips of terrain adjacent to roadways) or create other features that can attract carnivores and expose them to a higher risk of mortality by vehicle collision. In addition to other anthropogenic resources provided by roads (e.g., roadkills, garbage), can influence carnivore habitat use by attracting them close to roads and exposed herbivore to increased mortality risk by vehicle collision (Planillo et al., 2018). Smith-Patten and Patten, (2008) also revealed that roadkill is easy prey, albeit coming with a high risk of the scavenger becoming the scavenged. Furthermore, cheetah as an endangered species was hit by vehicle representing a species of conservation concern and therefore may be used as a flagship species (Freitas et al., 2015) for conservation in the area.

It was also found that, wild mammal roadkill was significantly higher during the dry than wet season. This finding is consistent with that of Meza-Joya et al. (2019) who pointed out that the increase in wild mammal roadkill during the dry season is linked to species mating seasons, when individuals tend to move more frequently or longer distances to find a mate and grazing resource, that force animals to foraging in larger areas to find food and thus supported our third prediction. This finding also concurs with report by Arévalo et al. (2017), who reported that seasonality is an important factor that may determine roadkill frequency in some wild mammal species because of their presence in higher numbers during their breeding season. However, seasonal differences in wild mammal roadkill may be related to the persistence time of carcasses during rainy seasons, since the action of rainfall and runoff promotes faster degradation of carcass and washes away carcass debris (Meza-Joya et al., 2019).

Specifically, more wild mammal roadkill were observed along good or smooth roads than along poor roads probably because of the failure of drivers to adhere to safe driving practices (Selvan et al. 2012). Similarly, more wildlife roadkill were recorded on the higher traffic roads, Drews (1995) and Selvan et al. (2012) also reported that the existence of public roads across protected areas has positively influenced roadkill incidences, due to high traffic and speeding factors. This finding support that of Santos et al. (2013), who reported that road characteristics and the quality of the surrounding habitat play a key role in shaping wildlife roadkill patterns. Generally, according to Santos et al. (2013), casualties will increase in good road sections with high traffic volume or low driver visibility, as well as where good or smooth roads cross high quality habitats, although this effect is species-specific.

Furthermore, we also found there were more single/individual carcasses than two or more carcasses per record. This finding is in consistent with that of the study by Collinson et al. (2015) who reported that roads pose a threat to the survival of individual animals and entire populations. Our encounter rates of 0.0156 animals /kilometer is considerably lower than those of the study reported by Njovu et al. (2019) of 0.04 and 0.02 animals/ kilometer in Kwakuchinja Wildlife corridor probably because our study was conducted on the gravel roads. Also, it was found that more mammals were recorded killed during the morning than afternoon hours. This is in support of the previous study by D'Amico et al. (2015) that temporal variations in mammalian roadkill patterns are associated with seasonal behaviors such as dispersal or migration, thus helping to predict outbreaks in the number of casualties.

CONCLUSION AND RECOMMENDATIONS

Our results show that body size and dietary type have a significant effect on a wild mammalian species' vulnerability to being struck and killed by a vehicle. Herbivorous wild mammals appeared to be especially vulnerable as compare to any other dietary type, while omnivores had the lowest absolute frequency of roadkill. This study, therefore, concludes that wild mammals' roadkill frequency can be explained by dietary type and body size. We suggest that mortality rates due to vehicles are noteworthy for wild mammals in the study area because species of conservation concern such as cheetahs were killed by vehicular traffic.

Our results have relevant implications for the establishment of measures to mitigate wild mammal roadkill impacts in our study area. Therefore, this study recommends modifying both human driver behavior (by limiting vehicle speed) which includes measures such as enhancing speed limits, adding signs to roads, educational outreach programs and animal behavior (by manipulating vegetation) and also removing potential carcasses on roads to reduce scavenger-related mortality.

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AWARENESS AND PARTICIPATION OF LOCAL COMMUNITIES IN THE CONSERVATION OF THE REINTRODUCED KIHANSI SPRAY TOADS

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ABSTRACT

Local community's awareness and participation in biodiversity conservation are critical. However, little information is known on local community awareness and participation in the protection of the re-introduced Kihansi spray toad and its habitat in the Kihansi catchment areas, since it was affected in 2009. The study aimed to determine the knowledge and participation of local communities near the Kihansi spray toad in the conservation of the reintroduced Kihansi spray toad and their habitats. The research was carried out in three villages around the Kihansi River Gorge, specifically in the Mgugwe, Udagaji, and Ukami. A cross-sectional survey was used to collect data from 365 respondents from villages surrounding the Kihansi Gorge using semi-structured questionnaires with both open and closed-ended questions. The measure of awareness was based on common characteristic of toas, identification and challenges facing the toad. Communities' awareness of the reintroduced KST was as follows: 98.9% (n=361) have heard of it, with a significant difference among villages (P=0.05). Furthermore, while 46.03 percent (n=168) have seen the toads before, only 27.67 percent (n=101) could identify them based on their physical characteristics. With insignificant variation across the three villages (P=0.236), roughly 43.01 percent (n=157) of people learned about KST from friends, while 33.15 percent (n=121) and 23.84 percent (n=87) learned from experts and local government officials, respectively. Local community conservation cooperation was low (30%), owing to a lack of awareness of the reintroduced KST by local people. KSTs and their habitats are affected by threats such as habitat degradation, pollution, fires, and invasive species predation. Local people should be more involved in habitat restoration, conservation education, and research on the reintroduced KST, according to the study.

Keywords*:* Extinct in the world, Conservation effort of Kihansi toad, creating awareness to local communities.

INTRODUCTION

Anthropogenic activities such as agriculture and infrastructure development contribute to species extinction (Akindele, *et al*., 2021, ; Niesenbaum, 2019; Rija *et al*., 2011; Ayivor, *et al*., 2020; Franco-Belussi, *et al*., 2020; Niesenbaum, 2019; Niesenbaum, 2019). Uncontrolled fires and unsustainable agricultural methods have harmful consequences for biodiversity protection (Kilawe, *et al*., 2020; Jhariya and Raj, 2014; Ngongolo and Nyundo, 2015; Sagasta *et al*., 2017; Syaufina, *et al*., 2018). Comparable negative effects on biodiversity, particularly endangered species, have been observed in areas such as Tesso Nilo National Park (TNNP), Riau Province, Sumatera, Indonesia (Syaufina *et al*., 2018; Jhariya and Raj, 2014). The KST and other endangered species in the Kihansi watershed environment might be affected directly or indirectly by the same factors.

The KST which is now being re-introduced, became endangered in 2009 (Nahonyo *et al*., 2019). The endangerment threats were linked to the building of the Kihansi dam for hydroelectric power generation, which resulted in habitat dehydration (Nahonyo *et al*., 2019, Rija *et al*., 2011). KST was reliant on mists emitted by the Kihansi River's waterfalls. The KST was threatened with species extinction because of habitat dryness due to water diversion as a consequence of the construction of the Kihansi dam. The success of the KST's reintroduction effort depends on the cooperation and participation of local populations living along the Kihansi River. Unfortunately, limited information is available on local community understanding and engagement in the long-term protection of the reintroduced KST.

In many parts of the world, biodiversity conservation is primarily carried out by scientists and professionals who are infrequent and unfamiliar with each ecosystem as compared to nearby native groups (Akindele, *et al*., 2021; Ayivor, *et al*., 2020; Spies, 2011). Because of their close contact with the environment, populations living within nature reserves are well-versed in community resource trends (Nyahongo, 2010; Uddin, 2017). They do have more incentives (direct attachment to biodiversity) than conservation managers, motivating people to manage their resources more sustainably (Ayivor, *et al*., 2020; Croteau & Mott, 2011; Nyahongo, 2010; Uddin, 2017). Other research has found that local community awareness and participation in biodiversity conservation have a significant impact on the long-term conservation of biodiversity species. In Nigeria reemphasized on a need to ramp up biodiversity conservation campaigns for enhanced awareness among Nigerians (Akindele, *et al*., 2021). Long-term studies also show that involving indigenous residents in conservation programs is by far the most effective form of sustainability (Roman *et al*., 2014; Akindele, *et al*., 2021; Ayivor, *et al*., 2020). For example, a study of local communities in the Magombera forest found that improved community awareness of biodiversity protection significantly influenced the forest's long-term conservation of biodiversity species (Mahulu *et al*., 2019). However, little information is known about local community's understanding and participation in the conservation of the reintroduced KST and its habitat within the Kihansi catchment area (KCA).

The goal of this study was to assess the level of awareness and participation of local populations near the KCA in the conservation of the reintroduced species (the KST) and their habitat. Knowledge and awareness and participation of local communities in the conservation of the reintroduced KST is critical to ensuring the long-term viability of the reintroduced KST in the wild.

MATERIAL AND METHODS

Study area

The research was carried out in three villages, Mgugwe, Udagaji, and Ukami, in the Udzungwa surrounding the Kihansi Kihansi Gorge located at 8°34'–8°37'S, 35°49'–35°51'E in the Udzungwa Mountains. The Udzungwa Mountains found in the Iringa and Morogoro regions of south-central Tanzania (Figure 1). In the Iringa-Morogoro areas of south-central Tanzania, the Kihansi watershed covers around 0.9 square kilometers (Vandvik *et al*., 2014). It reaches a height of 300 to 2,500 meters above sea level (asl). The Kihansi River flows in a north-south direction. The Kihansi River is 6 kilometers long, whereas the Kihansi Gorge is approximately 4 kilometers long and runs north-south. It can be located in a succession of Kihansi River waterfalls in Tanzania's eastern arc mountains' Udzungwa escarpment (Vandvik *et al*., 2014).

Data collection from local communities

A cross-sectional study from three villages surrounding the Kihansi Gorge. Data was collected from April to June 2021, using, using semi-structured questionnaires with both open and closed-ended questions. A total of 42 questions were used to gather information related to, demographic, social-economic, awareness, involvement, problems and mitigation, and long-term conservation of the reintroduced KST. The respondents aged 20 and up who had lived in the area for at least five years were from the three research communities. The communities were chosen based on their proximity to KC as well as the gradient in altitude. With the cooperation of local government leaders, participants from each village were purposively selected (based on age, period of stay in the area, and closeness to the KC). A total of 365 participants from the communities were chosen to participate in the interviews. A minimum of 5% of each village's responders were chosen from a list given by local government officials (NIST, 2020). The participants are Udagaji (n=100), Mgugwe (n=100), and Ukami (n=165). The population of the three communities was used to select the sample size.

Awareness of local communities about the re-introduced Kihansi spray toad

Questionnaires were utilized to gather information about the communities' knowledge, understanding, and attitudes toward KST. It also assessed the local communities' ability to recognize and identify toads based on common characteristics like size and reproduction mode. The KST toad's common feature has to be named by the people. Following that, they were given images of various toad species, including the KST, and asked to identify the KST from a list. Furthermore, the questions sought to determine whether the communities were aware of any potential challenges associated with the reintroduction of the KST, as well as any potential mitigating measures.

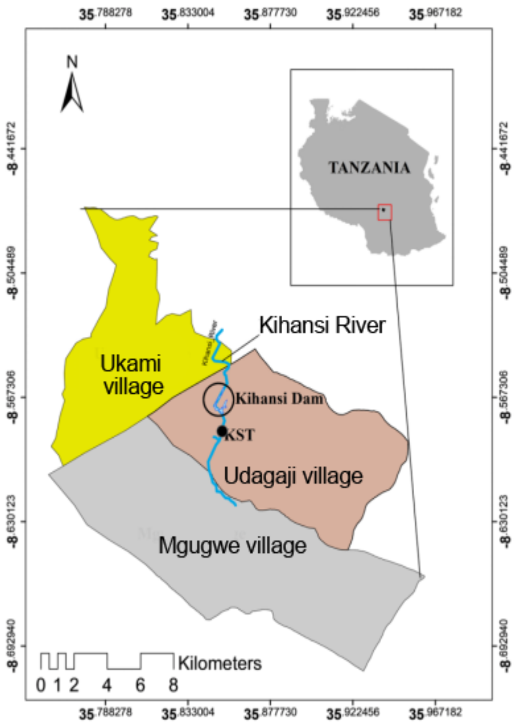

Figure 1. The three study villages around the Kihansi catchment area

Involvement of local communities in conservation

Respondents were asked to identify the people or agents responsible for the KST's preservation in this section. In addition, respondents were asked how they would contribute to conservation if they were involved in the conservation activities.

Data Analysis

The data were entered and organized into Microsoft Excel® (Microsoft Corporation, Washington, USA) before being analyzed with R statistical environment version 1.0.5 (http://cran.r-project.org/). Local community awareness, understanding, and perceptions on the KST were summarized using descriptive statistics, as was the ability to recognize and identify the toads based on their common traits, and whether communities were aware of any obstacles that the reintroduced KST would face. Percentages of responses were generated to show relative responses on awareness. The Kruskal Wallis statistical test was used to test the differences in respondents' opinions across the three villages on awareness of the KST, their involvement in conservation, challenges, and mitigation measures on the conservation of the KST.

RESULTS

Proportions of Respondents

A total of 365 people were interviewed in three villages representing high- and low-land communities. Two hundred people came from the lowlands, while 165 people came from a highland community. Mgugwe, Udagaji, and Ukami villages contribution varied in terms sex but not in age group (Table 1).

Local communities' knowledge on the re-introduced Kihansi Spray Toad

KST has been heard of by 98.9% of the 365 respondents, but their number varried across villages ($p<0.05$). Furthermore, 46.03% (n=168) had seen the toads, but only 27.67 % (n=101) could identify them based on their physical characteristics. With no significant differences between the three villages ($p=0.236$), 43.01 percent (n=157) of respondents learned about KST from friends, 33.15 percent (n=121) from experts, and 23.84 percent (n=87) from local government officials (Table 2).

Table 1. Proportion of respondents in the study area

SN	Variable	Classification	Mgugwe (n=100)	Udagaji (n=100)	Ukami (n=165)	U	P-value
1	Sex	Male	89	62	50.91	2.16	0.05
		Female	11	38	49.09		
2	Age group	Young	29	39	67.27	6.57	0.07
		Adult	50	44	27,27		
		old	21	17	5.46		

Note. P=probability value, U=nonparametric test (Kruskal-Wallis H test or he Mann Whitney U test), n= number of individuals interviewed

Table 2. The awareness of local communities on the re-introduced Kihansi spray toad

S/n	Variables	Level	Udagaji (n=100)	Mgugwe (n=100)	Ukami (n=165)	U	P-Value
1	People heard about KST	Yes	98	99	164	0.09	0.046
		No	2	1	1		
2	People who ever seen the toad	Yes	40	29	99		0.513
		No	60	71	66	2	
3	Where did they hear about KST	Friends	43	44	70		
		Local government leaders	19	13	55	2.6	0.236
		Experts	38	43	40		
4	People who can identify toads through feature	Yes	39	17	45	1.16	0.050
		No	61	83	120		
5	Feeling	Proud	98	100	162		0.050
		Sad	2	0	3		

Sources: (Sigala et al., 2021), Note. P=probability value, U=nonparametric test (Kruskal-Wallis H test or he Mann Whitney U test), n= number of individuals interviewed.

Involvement of local communities in the conservation

31.23%% respondents were involved in conservation of KST. Of these, 2.74 %, 1.92%, 1.64%, 1.37% and 19.45% were involved in conservation education, research, control pollution, fire management, diseases prevention, and conservation operations respectively. People's participation in conservation initiatives differed considerably across villages (P ≤ 0.05) (Table 3).

Table 3. Local community involvement in KST conservation and perceptions of who is accountable for the toad's conservation (Source: Sigala et al., 2021)

S/N	Variables	Level	Udagaji (n=100)	Mgugwe (n=100)	Ukami (n=165)	U	P
1	Involved in conservation of KST	Yes	43	30	41	0.26	0.050
		No	57	70	124		
2	How do they involve in conservation of KST	Educating others on conservation	3	4	3	0.13	0.018
		Conservation activities	29	15	27		
		Research	1	3	3		
		Reduce water pollution, controlled fire	0	6	0		
		Protecting the KST from diseases contamination	1	0	4		
		volunteering in conducting KST husbandry in captive breeding facility	10	3	7		
		Not involving in conservation	56	69	121		
0.343	Who is responsible for the conservation of KST	Expert	7	10	21		0.34
		Local community, government and experts	0	3		1.15	
		Local community and experts	8	6	4		
		Local community and TANESCO	6	6	3		
		Government and experts	8	6	16		
		NEMC, local community	1	1	3		
		TANESCO	0	15	32		
		Local communities	40	31	31		
		Government and local community	14	10	17		
		Don't know	14	12	35		
		Experts, people from abroad	2	0	1		

Challenges and mitigation measures suggested by local communities

The challenges facing the KST were sought from 365 respondents who were interviewed. Their responses were as follows; The challenges faced by the KST were habitat destruction (2.74%), diseases (4.66%), pollution (2.74%), lack of cultural and traditional practices (8.49%), fire occurrences, and predators (6.58%). The opinions of respondents varied in the three villages, particularly when these factors were interacting (P<0.05). On the other hand, respondents suggested some mitigation measures which include; a participatory approach to the conservation efforts between conservationists and local communities 9.32%, conservation education 9.59%, community conservation 10.41%, support from conservation donors 3.29%, restoration of degraded habitats 33.97%, cultural and tradition practices 10.14 %), and more research 4.11%.

DISCUSSION

Awareness of local communities on the re-introduced Kihansi Spray toad

Local communities were made aware of the reintroduced Kihansi Spray toad through hearing from friends, seeing the toad, specialists, and local government leaders, which differed per community. However, more work needs to be done to raise local community conservation knowledge of the reintroduced KST as their awareness is still low (Sigala *et al* 2021). Other people, for example, were unable to identify the toad based on physical characteristics such as size and reproduction methods. It's critical to raise awareness about the reintroduced toad conservation so that local communities can help. If no awareness creation to the communities, they threated the habitats of Kihansi spray toad though agriculture, fertilize application which in turn alters the water quality of the river as has been shown in other study (Sigala *et a*l., 2022).To a large measure, true biodiversity conservation action plans are determined by the amount of awareness and participation of local populations (Akindele, 2021). Other research has demonstrated that local community awareness of conservation initiatives has aided in the protection of animal species like KST and ecosystem preservation (Akindele, 2021; Ayivor, *et al*., 2020; Mwakaje *et al.,* 2013). Uddin (2017) For example, Akindele (2021) highlighted the need for education, awareness, and training among Nigerians in the conservation of natural regions such as the Omo Biosphere Reserve and Kainji Lake National Park in Niger State. In Bangladesh, outreach to local populations boosted understanding of the importance of maintaining animal species and their habitats (Uddin, 2017). This is in line with research conducted in the Magombera forest, which is part of the Udzungwa ecosystem, which also includes the Kihansi gorge (Mahulu *et al*., 2019; Ngongolo *et al.*, 2019). This study found that conservation education raised local community awareness of endemic and endangered species such as Kinyongie magomberae, Kipunji (Rungwecebus kipunji), Matundu Dwarf Galago, Iringa/ Uhehe/Udzungwa Red Colobus (Piliocolobus gordonorum), Nectophrynoides tornieri, and Sanje Mangabey, all of which are globally rare and found in the Ud (Kibbassa, 2014; Mahulu *et al.*, 2019; Ngongolo *et al*., 2019; Vandvik *et* *al.*, 2014). This has been accomplished through participatory conservation and obtaining support for animal protection. The success of their conservation path, like that of other animal species, is dependent on community knowledge. An increase in local community understanding of the reintroduced KST and KC is expected to improve their sustainable conservation.

Involvement of local communities in the conservation

Local communities' participation in conservation activities was observed in a variety of ways, including educating others, participating in research, reducing water pollution, controlling fire, and protecting the KST from disease pathogen contamination, as well as direct participation in conservation activities. Overall, 30% of local communities interviewed were involved in conservation efforts. Low participation is linked to local populations' lack of awareness of the reintroduced KSTs. According to previous studies, (Andrade & Rhodes, 2012; Uddin, 2017), it becomes extremely difficult to conduct conservation initiatives when local communities are excluded from biodiversity management and their needs and wants are ignored. Local communities must be encouraged to participate in the conservation of reintroduced KSTs, particularly in these locations. Local populations in Uganda's Bwindi Impenetrable Forest and South Africa's Tsitsikamma National Park engaged in unlawful activities such as deliberate fire initiation to force conservation plans to include them, according to studies from other African countries (Andrade and Rhodes, 2012). According to other studies, local communities can help conserve biodiversity by participating in anti-poaching patrols, donating land for conservation, and participating in research and outreach projects (Roman *et al*., 2014; Uddin, 2017). This is in line with the findings in Dodoma which concluded that, for healthy conservation of the restored and afforested areas, proper monitoring which involves local communities around the point of action is essential (Ngongolo and Kilonzo, 2022). The conservation of coral reefs and mangrove forests is improved when local communities are involved in conservation programs, according to a study done in Kenya (Kearns, 2010). An integrated approach to conservation techniques can help to improve this. Other significant stakeholders in the protection of toads, according to this study, are experts, the government, Tanzania Electric Supply Company (TANESCO), and the National Environmental Management Council (NEMC). Uddin, (2017), Niesenbaum, (2019), and Ayivor, *et al*., (2020) found that different stakeholders must be brought together to achieve higher conservation goals.

Challenges and mitigation measures suggested by local communities

According to respondents, the reintroduced KST suffers a variety of obstacles, including habitat destruction, infections, fires, pollution, and predation by invasive species. To make the reintroduction a success, local communities offered a number of approaches to overcoming the aforementioned obstacles. Good relationships between conservationists and local communities, conservation education, protection and proper feeding of the reintroduced toads, environmental conservation, ensuring security, community-based conservation, more research, restoration of degraded habitats, cultural and traditional practices, and others suggested that the toads be sent to the United States of America. Agriculture, industrialization, habitat degradation, poaching, infrastructural development, population growth, and pollution have all been recognized as major contributors to biodiversity destruction in various countries. (Birdlife International, 2018; Caro, 2015; Croteau & Mott, 2011; Mmbaga *et al*., 2017). To overcome these obstacles, an integrative conservation approach that includes local communities in biodiversity resource areas is required. Local communities are active in activities such as farming and grazing practices that have the potential to harm habitats, according to the findings of this study. In this scenario, engagement with local communities, which are major habitat destroyers for the toads, is essential to mitigate these dangers to the reintroduced KST. Croteau & Mott (2011) found that when local communities are interested in conservation, they are better able to notice population trends, which is crucial for conservation stakeholders to take appropriate measures to save species from extinction.

CONCLUSION AND RECOMMENDATION

Although, local communities are aware of the Kihansi conservation project, but most of them cannot identify toad. Their participation in the conservation of the Kihansi spray toad is low. The communities surrounding Kihansi catchment. Local communities are engaged in socioeconomic activities that jeopardize KST protection. To increase the awareness and participation, income generating activities can be encouraged or introduced in this area, such tourism, lodging to tourist. Income from tourism and other supports can help to facilitate the improvement socio-economic welfare of the local communities surrounding the area such as renovation of school, health centers, and local government offices.

Conservation education should be provided based on the implications caused by nearby local communities' socioeconomic activities. This involves integrating people in conservation initiatives such as outreaches, raising awareness about the effects of herbicide usage on biodiversity, such as the KST, and recommending they choose alternative methods that have fewer negative effects on species and their habitats. Also, female conservationists' need to be involvement is a strategy to encourage ladies in this area to join in conservation initiatives. Males are the only group of people who have to be involved in conservation initiatives, according to the majority of respondents, as experts are also males.

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STATUS OF ENDANGERED ASHY RED COLOBUS MONKEYS IN THE BURIGI-CHATO NATIONAL PARK: A PRELIMINARY ASSESSMENT FOR FUTURE SURVEYS

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ABSTRACT

The ashy red colobus monkey or Ugandan red colobus (Pilicolobus tephrosceles) is a forest dwelling primate which occurs in Tanzania and Uganda. IUCN listed it as endangered species partly due to predation by chimpanzees (Pan troglodytes) and anthropogenic activities outside protected landscapes. In Tanzania, they are found in Gombe Stream and Mahale Mountains National Parks, Mbizi Forest Reserve, Mbuzi Forest, Chala Forest, Ufipa Escarpment and Biharamulo game reserve which is currently part of Burigi-Chato National Park (BCNP). At present, the species distribution status in the country is largely not known. We aimed at obtaining baseline information on their status by i) confirming their presence/absence in the park ii) estimating group size and composition and iii) understanding their distribution across various habitats. We carried out presence/absence surveys for 17 days at Biharamulo and 8 days at Burigi zones of the BCNP along pre-determined routes. We also set camera traps at one location at the Kimisi zone besides opportunistic surveys carried out at this zone. We found many groups in the Biharamulo zone that borders Lake Victoria to the East. The camera traps provided the first evidence that red colobus monkeys also occupy western parts of the park (i.e., Kimisi zone). We preliminarily recorded 50 groups (including lone individuals) ranging from 1 to 86 individuals. The groups constituted different age categories namely: adults, sub-adults, juveniles and clinging infants. The presence/absence of clinging infants in most groups provides a promising future for this primate in the park. Forty-four individuals (88%) were recorded in the forest while 6 (12%) were in the woodland patches that are close to the forest. Individual density was estimated to be 204 individuals per km^2 in the surveyed area. Our preliminary findings indicate that the parts of the park close to Lake Victoria harbors a large abundance of this primate species. However, sampling efforts were highly biased in the Biharamulo zone. This study recommends further and well-planned surveys for red colobus in the park to help guide and design their appropriate conservation strategies.

Keywords: Abundance, Biharamulo, Baseline survey, Ugandan red colobus

INTRODUCTION

Red colobus monkeys (*Piliocolobus*) are highly threatened colobines (subfamily Colobinae), with majority of species classified either Critically Endangered or as Endangered according to the IUCN (International Union of Conservation of Nature) Red List (Struhsaker, 2010, Linder *et al.,* 2021). They are mainly evergreen forest specialists, even though some species (e.g., Zanzibar red colobus (*Piliocolobus kirkii)* and *P. temminckii*) can occupy open dry forest or mosaics of dry savanna woodland and forests (Galat *et al.,* 2009; Siex & Struhsaker, 1999; Starin, 1991; Struhsaker, 2010). Majority of the habitat types inhabited by red colobus species are increasingly under threat of alterations mainly due to human activities (Linder *et al.,* 2021). Red colobus occurs in the African tropical forest region (Struhsaker, 2010; Linder *et al.,* 2021). In Tanzania, there only three species of red colobuses, Zanzibar red colobus (*P. kirkii*) occurring in Zanzibar, Udzungwa red colobus (*P*. *gordonorum*) at the Udzungwa mountains and Kilombero and the Ashy red colobus (*Piliocolobus tephroscles*) occurring in the western parts of of Tanzania and Uganda (Struhsaker, 2010).

The Ashy red colobus monkeys (*P. tephrosceles*) are among the endangered primate species with an estimated population to be greater than 25,000 individuals in the world with Kibale National Park having the largest remaining population (Linder *et al.,* 2021). The species is only found in two countries namely Tanzania and Uganda (Struhsaker, 2005; Struhsaker & Ting, 2020). In Tanzania, the species is found in the Gombe Stream and Mahale Mountains National Parks, Mbizi and Mbuzi forests on the Ufipa Plateau and the former Biharamulo Game Reserve which is currently part of the Burigi-Chato National Park (Davenport *et al*., 2007, Kano, 1971; McLester *et al*., 2019; Moyer *et al*., 2006; Rodgers, 1981; Rodgers *et al*., 1984; Kibaja, 2022). Recently these monkeys have been discovered in the Ufipa escarpment and Chala Forest (Kibaja, 2022) and they may also be found in Lwafi and Lake Rukwa Game Reserves. The key threats facing Ashy red colobus monkeys are predation from chimpanzees, increased anthropogenic activities including deforestation, cultivation and logging (Fourrier *et al.,* 2008; Kibaja, 2022; Lwanga *et al.,* 2011; Stanford, 1998; Struhsaker, 2005; Watts & Mitani, 2002; Wrangham & Riss, 1990;). These threats are ongoing and they compromise their ability to play diverse ecological roles.

The Burigi-Chato is recently been gazetted as a National Park following an upgrade of three game reserves namely Kimisi, Burigi and Biharamulo with the species mostly found in the latter zone. Biharamulo zone is the most favorable area for the conservation of red colobus in the park due to its large size and many evergreen forest patches. The first status of this primate in the Biharamulo was reported in the 1980s (Rodgers, 1981). However, this survey was not very expansive and therefore the status of the species is largely unknown in the entire BCNP and therefore the need to gather data on its status.

Our preliminary reconnaissance survey aimed at getting information on the Ashy red colobus monkey and its abundance in the park. The study specifically aimed at i) confirming their presence in the park ii) estimating group size and composition and iii) understanding their distribution across various habitats. This information is critical as it provides a baseline population size needed for long-term monitoring of their changes (Plumptre & Cox, 2006; Plumptre *et al.,* 2013). Importantly, these data will help conservation biologists in planning future extensive surveys on this primate in the landscape.

MATERIALS AND METHODS

Study area

Burigi-Chato National Park (BCNP) was established in 2019) (Figure 1). It has an area of 4,707 km^2 (Burigi-Chato MZP, 2019) making it the fifth-largest Park in the country (Figure 1). It is located in North-Western Tanzania in Biharamulo, Ngara, Karagwe and Muleba Districts of the Kagera region and Chato District of Geita region as well as bordering Rwanda in the West and Lake Victoria in the East. The Park has both National and international significance as it acts as the wildlife heart between Tanzania National Parks (Ibanda-Kyerwa, Kigosi, Rumanyika-Karagwe and Rubondo) and Moyowosi Game reserve and Akagera National Park in Rwanda. It has six vegetation types which support more than 52 mammal species including the Ashy red colobus monkey (*Person observ*). The monkey is arboreal spending more time in the forest, particularly the Biharamulo zone which has vast riverine and dry land forests, water and food to support their life. The zone vegetation consists mainly of evergreen forest patches, woodland (dense miombo woodland, mixed *Combretum*-miombo woodland, Acacia woodland, wooded grassland and swamps or mbugas. About 95% of the data on the status of the Ashy red colobus monkey was collected in the Biharamulo area and only 4% in the Burigi zone and 1% in the Kimisi zone of the park.

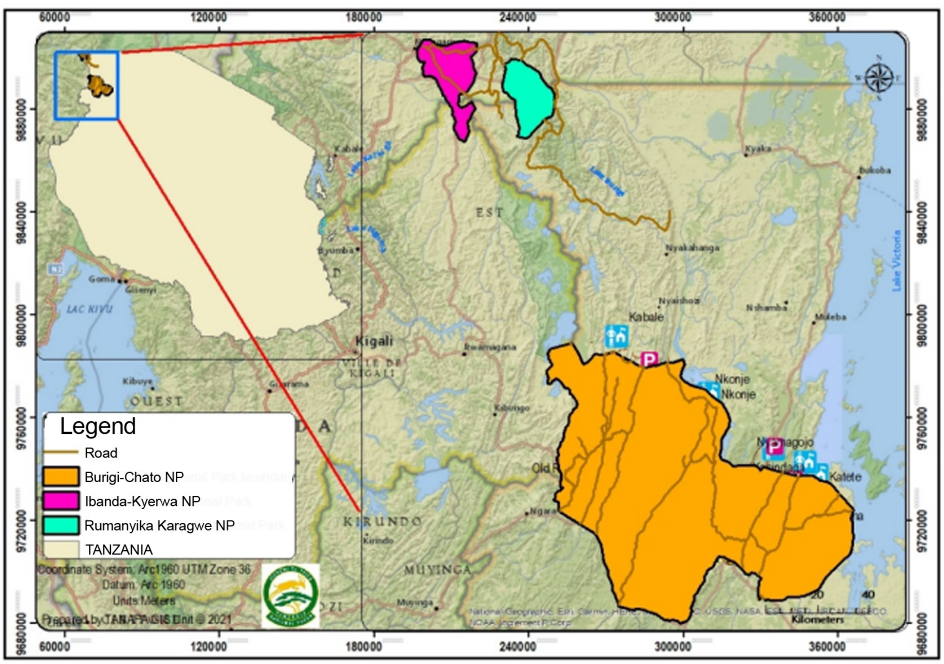

Figure 1: Map of the Burigi-Chato National Park

DATA COLLECTION

Presence /absence surveys were carried out along pre-determined routes from Google Earth Engine and previous records of the species from the park staff. The research teams first worked at the Biharamulo zone for 17 days and then in the Burigi zone for 8 days. Surveys were carried out between September and October 2021. We only conducted ad-hoc (opportunistic) surveys in the Kimisi zone because time was not enough to survey this zone. However, at the Kimisi zone, we set camera traps from October 2021 to February 2022 at the edge of forest patch in order to take photos of wildlife including red colobus utilizing the area. The field team was composed of one ecologist , one research assistant and two field assistants. The teams began surveys roughly at 8:00 am and ended at around 2:00 pm. Total distance was measured directly at the end of the survey by recording the length using the Garmin GPSMAP 64st tracking (Kibaja, 2022). The distance walked was varying in length between days (4 km to 8km), depending on the terrain, vegetation and the start time of the survey.

Upon locating a group of monkeys, the team spent 10 to 20 minutes (Pruetz & Leasor, 2002) recording their number, group composition (Adult, Subadult, Juvenile and Infants) following Struhsaker, 1975, sex of adults (Male and Female adults) (Kibaja, 2022), vegetation type (Forest, woodland, swamp and bushland), activity (Feeding, mating, resting, playing and grooming) and the GPS coordinates for mapping their distribution. However, survey teams did not record sighting or perpendicular distances from the animal to the observer because 50 m- fixed strip widths were used. This implied that all the visible individuals were counted within the fixed strip of 50 m, either side of the trail.

Datat analysis

The percentage/number of groups present in different habitats (different habitats based on vegetation types) were computed by dividing the number of groups found in a particular vegetation type by the total number of groups from all the vegetation types. We also estimated the density of red colobus based on fixed strip width. Fifty metres (50 m) was taken as one-half of the strip. Group density was computed as the total number of groups sighted at a fixed width distance divided by the total trail length multiplied by the fixed width. Individual density was obtained as a total number of individuals from all the groups sighted divided by the product of the trail length and fixed trail width (Azhar et al., 2008).

RESULTS

The survey covered a distance of 55.9 km and recorded 50 groups of *P. tephrosceles* (Table 1). Of these, 44 groups (88%) were found in evergreen forest patches and 6 groups (12%) in woodland. Many groups were found near Lake Victoria in the Biharamulo zone, but not in the western parts of the park (Figure 1). The group density was estimated at 8.9 groups per km^2 and the individual density was 204 individuals per km^2. The groups recorded were of varying sizes, with an overall mean group size of 22.8±SE 2.6 (range

1-86 individuals) and composed of individuals of different sexes and age categories. The mean number of clinging infants was 3 1±SE 0.4 (range 1-13). For the first time, the presence of this primate is reported in the Kimisi zone of the park from the camera traps (Figure 2).

Table 1. Number of individuals per group and number of individuals in different age categories

S/no	Ad Male	Ad Female	Sub-adult	Juvenile	Infant	Group size	Vegetation types
1	3	2	3	2	2	12	Forest
2	2	12	30	9	12	65	Woodland
3	0	0	30	11	8	49	Forest
4	4	10	19	12	6	51	Forest
5	6	13	24	30	13	86	Woodland
6	0	0	20	12	2	34	Woodland
7	0	0	10	4	7	21	Forest
8	1	3	6	5	3	18	Forest
9	4	17	17	13	9	60	Forest
10	2	10	5	11	8	36	Woodland
11	0	0	17	7	2	26	Forest
12	4	6	7	4	3	24	Forest
13	3	11	8	6	5	33	Forest
14	1	1	5	5	1	13	Forest
15	1	3	2	2	2	10	Forest
16	3	6	10	5	4	28	Forest
17	2	5	12	15	4	38	Forest
18	5	7	13	7	5	37	Forest
19	1	3	2	3	2	11	Forest
20	2	4	4	5	2	17	Forest
21	1	2	2	1	1	7	Forest
22	2	1	2	0	0	5	Forest
23	4	4	5	7	4	24	Forest
24	4	9	3	3	5	24	Forest
25	3	5	4	7	3	22	Forest
26	0	0	1	0	0	1	Forest
27	5	7	5	8	6	31	Forest
28	3	4	2	4	3	16	Forest
29	1	0	0	0	0	1	Forest
30	6	11	4	9	3	33	Forest
31	1	0	0	0	0	1	Forest
32	4	5	7	5	5	26	Forest
33	1	1	3	1	1	7	Forest
34	3	1	4	4	0	12	Forest

S/no	Ad Male	Ad Female	Sub-adult	Juvenile	Infant	Group size	Vegetation types
35	1	2	5	3	2	13	Forest
36	1	1	0	0	0	2	Forest
37	4	5	9	4	4	26	Forest
38	5	5	6	5	5	26	Forest
39	5	7	7	5	4	28	Forest
40	3	7	5	2	3	20	Forest
41	4	0	0	0	0	4	Forest
42	2	4	3	0	0	9	Forest
43	2	2	0	0	0	4	Forest
44	3	2	0	0	0	5	Forest
45	1	0	4	0	0	5	Forest
46	7	11	25	7	3	53	Forest
47	4	5	4	8	3	24	Forest
48	5	6	6	2	1	20	Woodland
49	0	3	2	0	0	5	Woodland
50	0	0	9	7	0	16	Forest
Mean	**2.6**	**4.5**	**7.4**	**5.2**	**3.1**	**22.8**	
SE	**0.3**	**1.1**	**1.1**	**0.7**	**0.4**	**2.6**	

Figure 2. A photo of red colobus taken by a camera at a site in the Kimisi zone (Datum: WGS 84, UTM UPS, Zone 36: E 274701; N 9773780)

DISCUSSION

We preliminarily report on the current distribution and presence of the *P. tephrosceles* in the BCNP. *P. tephrosceles* was known to be present in the Biharamulo (currently part of the BCNP) since the 1980s (Rodgers, 1981). Since 1981, no study reported on the status of this primate in the Biharamulo. Our reconnaissance surveys revealed that *P.tephrosceles* occurs in the Burigi-National Park. The monkeys, however, were found in high abundance in the Biharamulo zone (Figure 1) where some of its parts are within Lake Victoria. Very few groups were found in the central part of the park known as Burigi and Kimisi. Photos of Ashy monkeys snapped by camera traps at the Kimisi zone of the park close to Rwanda indicates that this primate may be extensively distributed throughout the park. The observation of this primate at Kimisi zone serves as the first observation ever to be made in the park because Rodgers (1981) only mentioned the Biharamulo Game Reserve (Nowadays part of the BCNP). However, our survey indicates that the Biharamulo and the area close to Lake Victoria is a key area for future surveys of Ashy red colobus monkeys.

Despite our encounters with many groups (50 groups), this number is not entirely accurate due to firstly, our survey method did not include complete counts. Complete counts are believed to be accurate method for obtaining accurate primate population size (Harcourt & Fossey 1981; Davenport *et al.,* 2007; 2008; 2019) ever though its applicability may be very time consuming and difficult in large area and large groups with extensive range overlaps (Campell *et al.,* 2016; Struhsaker 2010). Secondly, it is important to note that sampling effort was not standardized between different parts of the park. Our surveys were biased as they concentrated mainly in the Biharamulo zone of the park. The observation of many groups of *P. tephrosceles* in evergreen forest than woodland vegetation was similarly reported by Moyer *et al.* (2006) and Kibaja (2022). The monkey being an arboreal and folivorous, may in part explain why a large proportion of groups were found in patches of the evergreen forest of BCNP compared to woodland vegetation types. Their occurrence in evergreen forest patches may indicate that these patches are key habitats for this primate in the park. In our survey, the groups of *P. tephrosceles* we recorded with variable in size; including lone individuals. A myriad of factors has reported to influence the variation of group sizes in *P. tephrosceles*. These include habitat quality, predation pressure and behaviour patterns (e.g. fission-fussion and aggregation (Struhsaker, 2010). Since we have not gathered evidences of predation and red colobus hunting by humans in the park, then we may preliminarily infer fission-fission and aggregation to possibly affect the observed variation of group size and composition in the BCNP.

Lone individuals were also recorded in Kabogo forest patch within the Greater Mahale Ecosystem (Kano, 1971). Our observation of solitary individuals in the BCNP does not provide impression that these are solitary. It could be because that these individuals were left behind when groups dispersed to other forest patches. Our survey method and that used by Kano (1971) are highly affected by fission-fusion in which lone individuals temporarily separated from the group could be treated as a group on their own right. When fusion-fission occurs, may make several sub-groups from a previously large group that has to undergo fission are regarded as different groups (Struhsaker, 2010). We suggest an appropriate method to accommodate the effects of fusion-fission or aggregations and other factors. Also, when aggregation (association of more than one conspecific social groups) occurs, aggregated groups may be mistakenly treated as single groups in their own right (Struhsaker, 2010; Kibaja, 2022). In the present survey, the density of the monkeys was very high, but again this does not provide the impression that they are quite abundant in the area. The method for density calculation (distance sampling) using strip width may overestimate densities.

Therefore, the number of groups, their sizes and estimated densities may not reflect the reliable figures to infer population structure in the park because our survey technique failed to take into consideration the fission-fusion patterns. We recommend future surveys to consider an appropriate method that can produce a reliable number of groups, group size and individual densities. The complete count method may help determine a reliable number of groups, group size and density. We also conclude that the *P. tephrosceles* may be available widely across the park, with the Biharamulo zone being the hotspot.

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LEGALIZING ACCESS TO WILD MEAT: PEOPLE'S PERCEPTIONS AND FACTORS INFLUENCING ACCESS TO WILD MEAT IN DODOMA

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ABSTRACT

Amidst escalating urban populations, a better understanding of the underlying factors and challenges influencing access of wild meat provides a roadmap to a sustainable wild meat business in Tanzania. This study assessed people's perceptions, views, ability, willingness, and challenges of accessing wild meat. Data was collected using questionnaire and semi-structured interviews and analysed using SPSS version 26. Results show that, unique taste and health benefits of wild meat influenced willingness to buy wild meat. 93% and 84% of the population were able and willing to buy wild meat, respectively. Furthermore, religion influenced people's willingness to buy wild meat. Low-level supply of wild meat was influenced by insufficient capital, bureaucracy and inefficient hunting blocks. These findings demonstrate the viability of wild meat business if the corresponding impediments are addressed. Additionally, chances of prevalence of illegal hunting for bush meat are highlighted in absence of effective control of the wild meat business.

Keyword: Access, butchery, illegal hunting, wild meat.

INTRODUCTION

An apprehension of illegal hunting as driven by poverty and its impacts on the conservation of wildlife is of utter importance throughout the world (Gluszek et al., 2021, Olmedo et al., 2021). In Africa and beyond, consumption of wild meat accelerates the decline of wildlife (Kiffner et al., 2015, Mfunda and Røskaft, 2010, Rija and Kideghesho, 2020). Conservation of wildlife and utilization mainly via illegal off-take of wild meat is inseparable in developing countries like Tanzania, where protected areas work at higher costs to ensure wildlife sustainability. Admired by visitors, wildlife is at the same time a burden to the people who hardly derive benefits from its existence. However, urban communities are privileged to enjoy wild meat through illegal sources given the higher costs in accessing wild meat legally (Ceppi and Nielsen, 2014).

There is a growing urban demand for wild meat and despite the efforts that keep on being directed to curtail poaching, it is still hard to halt people who by the history of interaction have been dependent on wildlife resources for subsistence and income generation. (Kideghesho, 2008) suggests augmenting traditional practices (an alternative less expensive means of conservation) towards ensuring the conservation of wildlife species over law enforcement approach which is often faced by insufficient resources. Nevertheless, such efforts must be complemented by sustainable utilization of wildlife a practice that has existed since time immemorial (Baldus and Siege, 2001).

The growing human population in urban areas with limited livelihood opportunities has led to a surge in demand for wild meat, primarily for subsistence and income generation (Knapp, 2012, Manyama et al., 2019, Milner-Gulland and Bennett, 2003). Baldus and Siege (2001) reckon that, poaching does not end with law enforcement, rather considering that poor people around protected areas have fewer livelihood alternatives, their economic incentives must be changed. A number of factors effectuate change in demand for wild meat including; technological change, alternative supply and cultural lifestyle preferences. Familiarity, culture and traditional inheritance (as identified by Masomera and Muir-Leresche (1998) and Alarape et al. (2017) among other studies) increase the demand for bushmeat because it provides trophies for cultural artefacts and medicinal values (Robinson and Bennett, 2000, Kideghesho, 2008, Knapp, 2012) . Whatsoever the reasons as to why illegal hunting is still unabated to date in Tanzania's protected areas, the benefits that the local people acquire from this illegal activity outweigh the risks in their shoes (Alarape et al., 2017, Knapp, 2012).

Amidst escalating human populations where sustainability of wildlife is under threat, the demand for alternative source of protein and monetary benefits from illegal hunting rises the level of threat to wildlife sustainability. As the human population grows, the demand for food increases, creating a need for sustainable utilization and conservation of wildlife resources (Cooper, 1995). The involvement of people in wildlife resources conservation as driven by the urge to reduce poaching and improve conservation through time in Tanzania is not enough per se, rather people should as well be involved in the utilization of wildlife resources, '*a resource which can satisfy their basic needs, if used wisely*' Baldus and Siege (2001). In the fear that legalizing wild meat off-take may accelerate poaching, it is rather suggested by the economic theories (Milner-Gulland and Bennett, 2003) that legalizing access of wild meat at acceptable and affordable standards (Nielsen et al., 2016) could help reduce unsustainable hunting and enhance wildlife conservation.

The wild meat industry should be designed to align with local communities' perceptions and take into account the various factors that impact their access to this resource (Baldus and Siege, 2001, Kiffner et al., 2015, Nielsen et al., 2016) . Chosen for its taste, cultural connotations, status and luxury (The citizen, 2020), wild meat remains to be an indispensable source of protein among the urban populations. Therefore, without considering local communities' perspectives and adapting the legal access to wild meat to align with their attitudes and current realities, it will be difficult to discourage illegal hunting and promote sustainable utilization of wildlife resources by the community. The establishment of wild meat industry will also be ineffective, and correcting the resulting consequences will require significant investments of wildlife, financial, and time resources.

Apparently, whilst little is known of people's perspectives on legal access of wild meat, vast studies have been done on bush meat consumption (Milner-Gulland and Bennett, 2003, Fa et al., 2003, Nasi et al., 2008, Ntiamoa-Baidu, 1997, Woodburn, 1980) with several studies confined to the Greater Serengeti Ecosystem and the local communities surrounding it (Mfunda and Røskaft, 2010, Moro et al., 2014).This has resulted into policies based on the assumption that the economic and the ecological constraints of all people throughout the country are the same, and that one solution therefore fits all (Martin et al., 2012). A more practical solution to illegal hunting in Tanzania can be found not in concentrating to provide a legal access of wild meat to the people but through integrating their views, demands, and income to the sustainability of wildlife resources (Milner-Gulland and Bennett, 2003). From an urban community perspective, this study therefore assessed the views and disposition of people relative to legal access of wild meat. It identified whether establishing wildlife butcheries will be economically sustainable and assessed the people's views, ability, willingness and challenges faced by butchery owners to access of wild meat. The findings provide lead for adequate planning of the wild meat business in Tanzania without which the initiative may fail. The study also identified important areas where the government can intervene as well as the presumptive challenges which may emerge as a result of implementing this initiative.

MATERIALS AND METHODS

Study area

This study was conducted in Chang'ombe, Majengo, Sabasaba, and Mailimbili areas in Dodoma Urban in Dodoma region (Fig.1). The district has in recent years witnessed increasing population and urbanization following mass movement of public offices and entire State functions to Dodoma Capital City. Although not popularized by presence of protected areas, residents have for a long time accessed wild meat illegally from inside and outside protected areas such as Swagaswaga and Mkungunero Game Reserves. Wild meat butchery was opened in Dodoma in December 2020 providing opportunity for legal access to wild meat to residents.

Data collection

A cross-sectional study design was employed to collect data using structured and semi-structured questionnaires, as well as semi-structured interviews. Key informant interviewees, including three butchery owners and one TAWA officer, were selected through purposeful sampling techniques (Shairp et al., 2016, Hema et al., 2019b). Both quantitative and qualitative data were collected. Information collected from key informants included current demand of wild

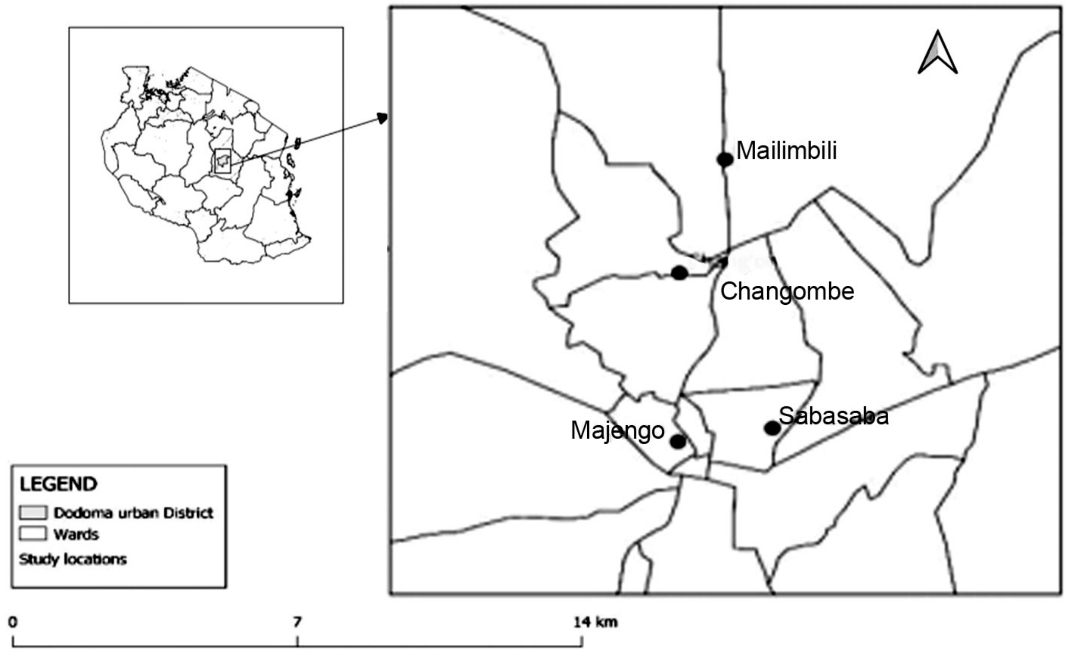

Figure 1. Map of Tanzania showing the (a) location of Dodoma region in Tanzania (b) Map of the study area showing the selected locations

meat and challenges of its corresponding operation. In addition, questionnaire respondents were selected conveniently. Information collected from questionnaire respondents included demographic information, awareness on availability of wild meat, drivers and challenges to opting and accessing wild meat. (Wassenaar, 2016) Participants provided their consent to participate and their identity was kept confidential to ensure anonymity. Data collection was conducted with permission from the local government authorities.

Data analysis

Qualitative and statistical analyses were used during data analysis (Bryman and Cramer, 2009, Pallant and Manual, 2007). Thematic analysis was used to analyse qualitative data while statistical data was analysed using Statistical Package for Social Science (SPSS) version 26. Ability to buy fish, beef and other non-wild sources of protein were used as indicators of an individual's ability to buy wild meat. Alternative protein sources as indicated by the result were in a descending range of sumptuousness starting from fish, fish and beef, beef to other sources of protein particularly beans. This method of measuring ability is in line with a recent study (Lau et al., 2018) which measured relative wealth based on presence of household items and facilities among other factors associated with the expense of each. Additionally, chi-square test (Hariohay et al., 2018) was used to test whether age, religion, education level andand livelihood form influenced willingness to buy game meat.

RESULTS

Demographic characteristics of the respondents

Using questionnaire survey, a total of 200 respondents were interviewed in this study amongst which 70.5% (n=141) were males. In educational levels; respondents were classified into those who attended primary school (47%), secondary school (31.5%), college/university (17.5%), and those who had no formal education (4%). Religion wise, 62.0% were Christians and 38.0% were Muslims. The respondents' forms of livelihood were categorized into self-employed (71.5%), employed (18.0%), and unemployed (10.5%). Majority of the respondents were in the age group of 31-60 years (49%) followed by those in the age group <30 years (43%) and those in the age group ≥61 (8.0%).

People's views with regard to access of wild meat

Willingness to buy wild meat

84% of the population were willing to buy wild meat while 16% were unwilling to buy wild meat. Out of the 200 respondents, 77% were able to provide reasons for buying wild meat while 10% were unsure and the remaining 13% of the respondents provided no answer. Results in Fig. 2 show that wild meat was preferred for its perceived appealing taste, followed by other reasons such as cultural connotation, affordability and availability while others were not sure of the motive. Also results show that respondents would be unwilling to buy wild meat due to its perceived unavailability, lifestyle, unaffordability and religious constraints and others were unsure why they would be unwilling to buy wild meat (Fig. 3). Further, results revealed variation of religion with willingness to buy game meat (X^2= 3.87, df= 1, p=0.049)

Factors influencing access of wild meat

Majority of the respondents (54.12%) were compelled by a mere demand to an alternative protein source, others by rewarding medicinal values (16.47%) of game meat, and others hoping to reap benefits of conservation through utilization of wild meat as a reward to living in harmony with wildlife and aiding in conservation (12.35%). Other factors were a concern for wildlife population decline; a lifestyle accustomed to consumption of livestock meat; a feeling of prestige to access of wild meat; while the remaining respondents were less interested to wild meat due to its unreliability (Fig. 4).

People's ability to buy wild meat

Ability to buy wild meat was measured on the alternative choice of protein that respondents preferred relative to wild meat. Those who had only fish (57.95%, n=116) and both fish and beef (14.87%, n= 30) were considered able to buy wild meat, those who had beef (20%, = 40) as an alternative source of protein were considered able to buy wild meat while those who opted to other sources of protein (4.10%, n=8) such as beans were categorized as least able to buy wild meat. The remaining 3.08% (n=6) were unable to buy wild meat. The price people are willing to pay for wild meat. Majority (35%, n= 61) of the respondents were willing to pay a price equal or above 7000 Tanzania Shillings per kilogram of a wildmeat (Fig. 5).

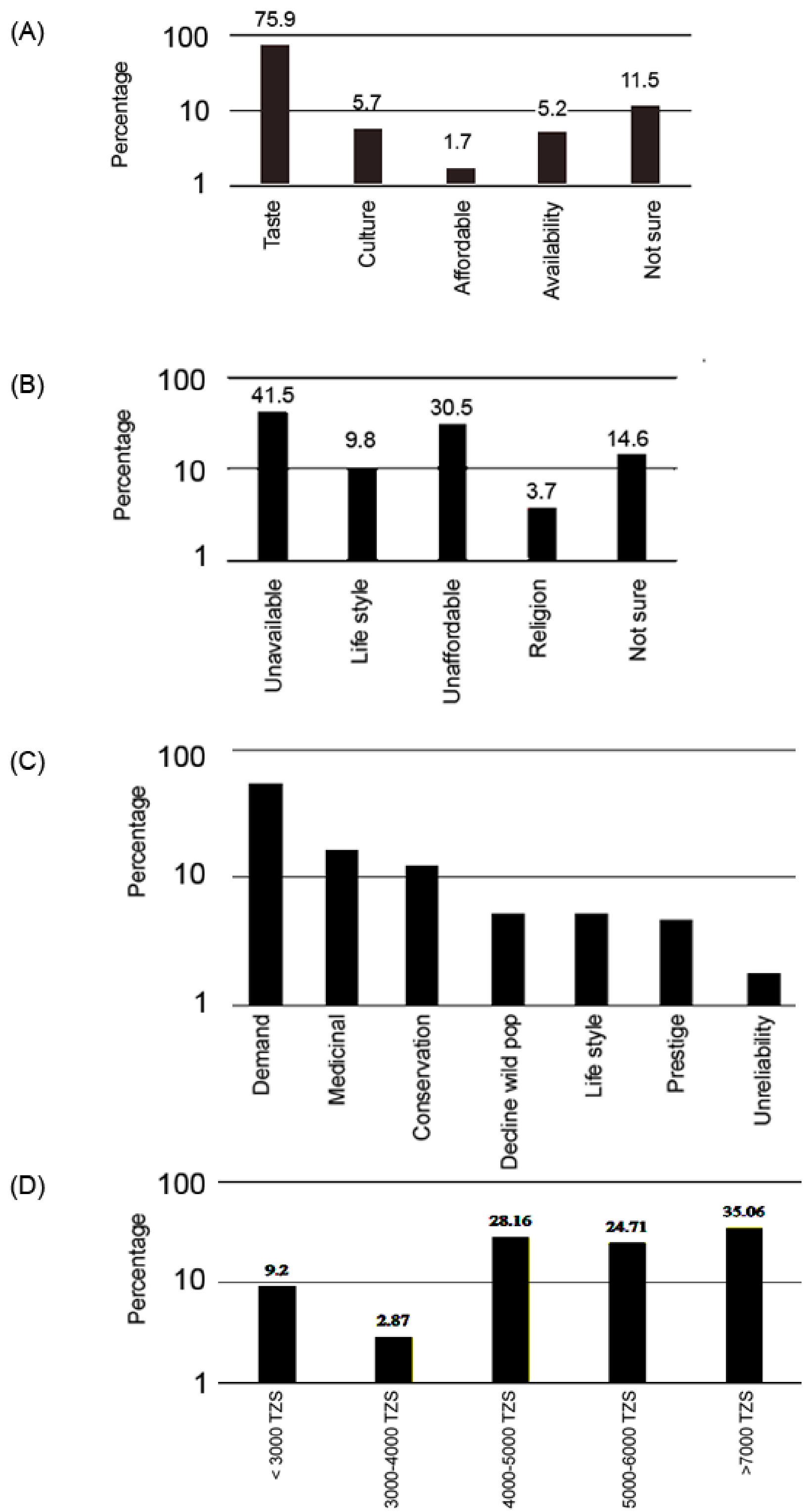

Figure 2. Factors for willingness to buy wild meat (A), unwillingness to buy (B), views regarding access to wild meat (C), and the price that people are willing to buy wild meat (D)

Table 1: Quotes of key informant respondents describing the status of demand, preference and importance of access of wild meat. (R= Respondent)

Category	Theme	Quote
Demand	Status of Demand	*I have orders from about 900 customers, but right now we are not allowed to hunt for a while. (R2)* *The demand is really high, the wild meat does not last a day in the butchery, people keep complaining why we never bring enough to suffice their demand. (R3)* *Compared to its supply, the demand for wild meat is very much higher. (R4)*
	Type of wild meat in great demand	*Most of my customers in ranking prefer impala, hartebeest and eland meat. (R1)* *They can hardly tell which specie it is, but if I should rank, they prefer Impala, hartebeest, eland and dikdik. (R2)* *As long as it is wild meat, they rarely make choices, but as far as I can tell, a few prefer buffalo meat while the majority would go for impala, hartebeest and eland meat. (R3)*
Preference	Medicinal value	*I have a few special customers who have medical restrictions from consuming meat, but wild meat causes them no harm. (R1)* *The wild animals consume a larger variety of plants unlike livestock, so they are naturally a medicine. Even those allergic to meat can consume wild meat without any trouble to their health. (R2)* *Wild meat is a good recommendation for people with health problems, it is a good cure of human ailments. (R3)*
Poaching	Solution to poaching	*People would rather buy legal wild meat than illegal wild meat which is borne of criminal offence. (R4)* *While we hunt in rotations, it is practically a workforce for indirect patrols. (R2)* *Since the establishment of wild meat business, poaching has been forced down in the areas we hunt and supply wild meat. (R1)*

Challenges faced by wild meat butchery owners in access of wild meat

Table 2: Quotes of key informant respondents describing their motivation to wild meat business, challenges they face in access of wild meat. (R= Respondent)

Category	Theme	Quote
Motivation	Business opportunity	*I saw an opportunity to grow financially in the wild meat business. (R1)*
Challenges	Hunting blocks	➢ *It is hard sharing hunting blocks with the local hunters (R1)*
		➢ *Difficult to attract investors, this business requires a huge capital (R2)*
	Insufficient capital	➢ *Entry fees keep on increasing, and you have just meet the minimum requirements for a hunting block (R1)*
		➢ *Butchery owners lack thorough facts about the business, thus vulnerable to loss investment capital (R4)*
		➢ *DGOs are likely to reduce amount of meat supply below that customers are expecting or demand in the market (R3)*
	Bureaucracy	➢ *I had my hunting permit which was revoked, I made follow ups to the DGO who directed me to TAWA officers who in turn directed me back to the DGO, they just put me in dilemma (R2)*

DISCUSSIONS

Results of this study provide useful insights regarding the wild meat business in Tanzania specifically in urban areas where population and demand for alternative sources of protein are both escalating (Ingram et al., 2021, Ingram, 2020, Booker and Wilson-Holt, 2020). Both Ingram (2020) and Luiselli et al. (2020) affirm that urbanization effectuates demand for wild meat which is in line with the findings of this study.

People's views with regard to access of wild meat

Results indicate that there is a good number of factors that weave a thread of views that people have towards access of wild meat. A large population would choose wild meat over livestock meat for its good taste. Other factors influencing people's views regarding access of wild meat are culture, and the perceived affordability and availability of wild meat. Hoffman et al. (2005) and Alarape et al. (2017) pointed out similar views with regard to access of wild meat with majority choosing wild meat for its unique taste. A little percent of individuals who view wild meat as a cheap protein source have been accessing wild meat through illegal sources at a relatively cheap price and that has shaped their view of wild meat as an affordable protein source.

A growing demand for wild meat is associated with its perceived medicinal rewards. Individuals who would be willing to buy wild meat for its medicinal values hold the notion that wildlife consumes a variety of natural plants and unlike livestock, wild meat is free from chemicals and therefore safer for consumption. Conversely, individuals who were negatively disposed towards access to wild meat were influenced by factors such as lifestyle which is likely to change with exposure over time, higher prices for those who had never accessed wild meat legally, and religious restrictions for Muslims. Similar results were obtained in a study conducted to understand urban demand for wild meat in Vietnam (Shairp et al., 2016) in which wild meat was associated with good quality, taste and health benefits. Consumer's preference of impala, hartebeest and eland over buffalo is rooted in the perceived softness of the meat.

People's willingness to buy wild meat

Individuals might be able but unwilling to buy wild meat. Results indicate that all respondents except for the 16.6% were willing to buy wild meat. This result reveals the fact that people are willing to buy wild meat whether it is provided legally or otherwise. A study conducted in Burkina Faso (Hema et al., 2019a) where there were apparently no legal markets for wild meat (seldom wild meat is sold at the wildlife department offices and a few authorized restaurants) revealed that the consumption of wild meat lasts throughout the year through illegal sources. Contrary to Hema et al. (2019a) in which consumption of wild meat is not influenced by the socio-economic characteristics, religious affiliation influences willingness to buy game meat (Masomera and Muir-Leresche, 1998).

Furthermore, an assessment of the price that individuals would be willing to pay for wild meat revealed that individuals tend to relate prices of wild meat to its substitute sources of protein particularly beef. This may be the reason why majority of people were willing to pay more than 7000 /= TZS per kilogram of wild meat which was the same price for beef in Dodoma. Majority of respondents perceived wild meat as a protein source with both good quality and good taste and hence more valuable given its specialness aroused by its rarity (Masomera and Muir-Leresche, 1998). Additionally, individuals who are willing to pay higher prices were aware of the costs incurred in the management of wildlife wrapped in perceived views of their rarity as a source protein given the legal boundaries involving consumption of wild meat. In a way, the price for wild meat may effectuate people's willingness to buy wild meat (Udomkun et al., 2018) and therefore an important parameter to be assessed. Nonetheless, choice of some respondents to pay low prices for wild meat was influenced by the fallacy that it costs almost nothing to raise wildlife in relation to livestock as wild animals grow naturally in frontiers and there were plenty.

Challenges faced by butchery owners in accessing wild meat

Results indicate bureaucracy, insufficient capital and an unreliable supply of hunting blocks as impeding challenges in accessing wild meat. Booth et al. (2021) points out that while unsustainable hunting practices and wildlife trafficking prevail, regulatory hurdles and market volatility may arise and indirectly impact the ability of butchery owners to access and sell wild meat. The stage for establishment of wild meat business has not been properly set from its inception in Tanzania, making it difficult for butchery owners to turn a profit. They are often disappointed to discover that they cannot have full control over their business, and there is no assurance that they will be able to recover their expenses or at least break even, due barriers to entry and profitability such as; fees, reliability, and duration of hunting permits. Alternatively, Taylor et al. (2020) argues that besides creating job opportunities and income generation for the local communities, game meat industry can provide a sustainable alternative to hunting and poaching, as it incentivizes landowners to conserve wildlife and invest in infrastructure and management practices that enhance animal welfare and meat quality.

CONCLUSIONS AND RECOMMENDATIONS

The study reveals an increasing demand with a limited supply of wild meat in urban areas. Population increase presented a wider economic opportunity alongside a question of sustainability of wildlife. Considering the positively inclined views of people towards access to wild meat, an implication can be derived to account for higher prices of wild meat as compared to its substitute protein sources. Encouraging and supporting establishment of commercial wildlife farms is necessary to sustain the wild meat business. With effective law enforcement, the wild meat business can be structured as an additional tool against illegal hunting while trying to meet the growing urban demand for wild meat. Friendly policy and adequate legal frameworks need also to be enacted to ensure mutual benefit to both people and wildlife conservation.

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TRADITIONAL KNOWLEDGE ON WILD EDIBLE VEGETABLES AMONG LOCAL COMMUNITIES ADJACENT TO SERENGETI ECOSYSTEM, NORTHERN TANZANIA

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ABSTRACT

The communities residing adjacent to many protected areas are well knowledgeable about the use of wild-edible vegetables. However, this information is limited and incomplete in Serengeti ecosystem. Therefore, this study aimed at documenting the community knowledge on WEVs diversity and uses in Serengeti ecosystem. A total of 180 households from 6 villages residing in Ngorongoro and Serengeti districts were purposively selected and interviewed using semi-structured questionnaire. A total of 10 WEVs species belonging to 10 genera and 9 families were documented and were mainly used for domestic (92.8%) purposes. The most represented families were capparaceae (38.1%), Amaranthaceae (21.5%) and Tiliacea (17.7%) by Gynadropsis gynandra (37.6%), Amaranthus hybridus (21.0%) and Corchorus tridens (17.7%) respectively. Herbaceous plants make up the highest proportion of WEVs. Herbaceous plants indicated the highest proportion of WEVs. Households with lower income (88.4%) use more frequently WEVs than those of the higher income (11.6%). Moreover, female households (50.8%) possessed more traditional knowledge on WEVs including their identity and usage because they predominate the practice of gathering and cooking of these essential foods. In addition, majority of the household (86.6%) reported that the WEVs were decreasing in supply and difficulty in accessing them probably because of over harvesting and they were aware that WEVs were improving their livelihood and healthy status. We therefore call for urgent measures to protect and conserve WEVs in Serengeti ecosystem. Further research are need to document other unknown WEVs species in Serengeti and their nutritional status.

Keywords: Wild edible vegetables, traditional knowledge, local communities, ethnobotany, Serengeti ecosystem

INTRODUCTION

Wild-edible vegetables (WEVs) are plants with edible parts that grow naturally on cultivated areas. Globally, the use of WEVs has been a common practice for centuries (Satter et al. 2016, Duguma 2020) and is predominated by women and children (Bvenura & Sivakumar, 2017). WEVs are well known for their essential biochemical and nutritional importance as they contained good amounts of proteins, fats, carbohydrates, vitamins and minerals (Satter et al. 2016, Duguma 2020 and Powell et al., 2014). Also, WEVs provide moisture, fiber, ash and energy important for good health and prevention of diseases (Satter et al., 2016). Therefore, collection and consumption of WEVs have been a way of life to supplement dietary and medical requirements for many rural populations (Berihun & Molla, 2017; Naik et al., 2017) as well as in alleviating food insecurity and malnutrition.

In Tanzania, the use of WEVs has indicated to benefit food supply, income generation and biodiversity conservation (Mpasiwakomu et al., 2017). The same has been observed in communities around Serengeti ecosystem. For example, the study by Johns et al., (1996) found that 38 species of edible wild fruits and leafy vegetables were identified to be used by communities in Mara Region, in villages nearby SENAPA. Despite recognized nutritional and medicinal importance of WEVs in around SENAPA, only few formal studies have been conducted to explore their social-cultural and ecological values. This threats their proper utilization, exploitation, and sustainable management in the area. Therefore, this study aimed at documenting the community knowledge on the diversity, status and usage of WEVs in Serengeti ecosystem.

MATERIALS AND METHODS

Study area

The Serengeti ecosystem is approximately 25,000 km^2 (Fig. 1) and lies between 1^0 and 2^0S; 34^0 and 36^0E. It is composed of the Serengeti National Park (SNP) (14,763 km^2) and Ngorongoro Conservation Area (8,292 kmsq). The ecosystem a World Heritage Site and Biosphere Reserve, and forms the heart of the Serengeti Maasai-Mara Migratory Ecosystem of north-western Tanzania and south-western Kenya (Mfunda & Røskaft, 2011) . It is bordered by Lake Victoria, Ikorongo, Grumeti and Maswa Game Reserves, Ikona Wildlife Management Area (WMA), Loliondo Game Controlled Area (Roskaft et al., 2012). The ecosystem contains high diversity and concentrations of ungulates, large carnivores, and birds (Sinclair & Arcese, 1995) and the vegetation of the region is highly impacted by the large flocks of migratory wildebeest (*Connochaetes taurinus*), zebra (*Equus burchelli*), Thomson gazelle (*Gazella thomsoni*) (Sinclair & Arcese 1995**;** Thirgood et al., 2004). The land use type consists of the wildlife conservation area, human settlements, and agricultural and grazing lands. The topography of the area is characterized by a series of hills, and valleys to an extensive gentle and flat area. Altitudes vary from 1280 m to 2540 m above sea level and the climate of the area ha the annual mean rainfall ranges from 1,050 mm in the northwest to 550 mm in the southeast (Tarimo et al., 2017; Hariohay et al., 2022).

The annual migration of over a million wildebeest defines the ecosystem (Schmitt, 2010) following seasonal variations in rainfall and the availability of grazing across the ecosystem (Walelign et al., 2019).

The people in this region are either pastoralists or agro-pastoralists. The area west of SNP is populated by various tribes and ethnic groups, mostly agro-pastoralists; the main tribes are Ikoma, Sukuma, Taturu, Issenye, Kurya, Ikizu, and Natta. On the contrary, the region East of SNP is inhabited by the Maasai pastoralists and Sonjo agro-past (Hariohay et al., 2022). The Sonjo are agro pastoralists who have specialized more in agriculture than the Maasai, and they mainly grow maize, beans, sorghum and millet. Maasai are mainly

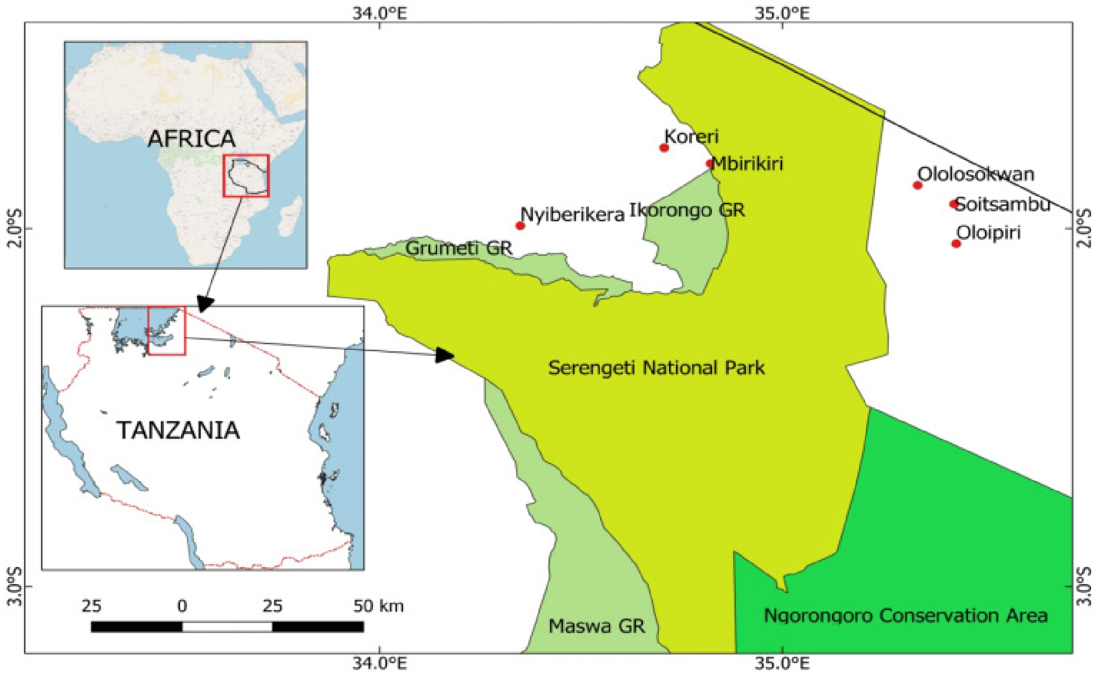

Figure 1. Study area map showing location of the study villages

Pastoralist, with livestock being central to their way of life, a style which has been viewed as being compatible with sustainable conservation (Hariohay et al., 2022).

Data collection

A cross-sectional survey was conducted in 6 villages (Ololosokwani, Soitsambu, Oloipiri, Mbirikiri, Koreri and Nyibererekera)(Figure1) between Jan-May 2018. Semi structured questionnaires were used to interview 180 respondents in the area. The respondents 30 individuals from each of the study village were randomly chosen based on age (15 – 95yrs) and gender (male, female). The questions were prepared in English but asked in ''Swahili'' language and then translated to the respective languages by the help of a tribe translators. Data collected included, recording the village name, age of the respondent, age class (youth, adults, elders), gender (men, women), GPS location of the respondent household, education level (no education, primary, secondary), level of income (small, large), knowledge of knowing and identifying WEVs (Which WEVs species are you using in your area?), accessibility of WEVs (easy, moderate, difficulty), WEVs availability (deceasing, increasing, stable), harvesting area (open area, game controlled area, game reserve, national park)and whether WEVs have contributed to improve their livelihood

Data analysis

Statistical Package for Social Science (SPSS, version 16.0) software was used for analyzing the data (http://www.spss.com) (Kirkpatrick and Feeney, 2010). The data were analyzed using descriptive statistics and the Pearson's chi-square goodness-of-fit test to determine the frequencies as well as differences among different variables. These variables included the following: Gender (consisting of two groups: men and women), Income category (consisting of two groups: small income and large income), Taxonomic category of WEV group (consisting of two groups: family and genus), Frequency of the WEVs use (consisting of four groups: daily, weekly, monthly and annually, Accessibility of WEVs (consisting of three groups: easy, moderate and difficult), WEVs availability (consisting of three groups: deceasing, increasing and stable), Harvesting area (consisting of four groups: open area, game controlled area, game reserve and national park), and Whether WEVs have contributed to improve their livelihood in the area (consisting of two groups: "Yes" and "No").

In addition, a linear regression analysis was used with response to the question "Which WEVs species are you using in your area?" as the dependent variable; and the following independent variables: age classes (youth, adults, elders), gender (men, women), education level (no education, primary, secondary education), income level (small, large), frequency of use (daily, weekly, monthly, annually), reasons for use (domestic, commercial), harvesting location (open area, game controlled area, game reserve, national park), availability status (stable, decreasing, increasing) and WEVs forms (herb, shrub). This method was used to determine which independent variables or factors explained the existing variation in traditional knowledge of WEVs use among the communities in the area. Since all the independent variables used were all continuous, therefore no assumptions about their distributions were made. For all tests, $p \leq 0.05$ was considered significant.

RESULTS

A total of 10 WEVs species of 181 individuals belonging to 10 genera and 9 families were documented and 92.8% were used for food and remained percent for income generation (Table 1). Out of 181 individuals WEVs, 98.9 % (179) were herbs (and others were shrubs (1.1 %). The mostly represented by families *capparaceae* (38.1%), *Amaranthaceae* (21.5%) and *Tiliacea* (17.7%) by species *Gynadropsis* gynandra (37.6%), *Amaranthus hybridus* (21.0%) and *Corchorus tridens* (17.7%; Table 1)respectively. Majority of WEVs species were harvested from the open area (n =149), and few others from the game controlled area (n =19), national park (n = 9), open are and game reserve (n = 3) and open area and national park (n=1). Leaves are the main edible part consumed through cooking. Further, 157 WEVs species (86.7 %) are decreasing, 14 species (7.7 %) are increasing and 10 (5.5 %) are stable and their differences are statistically significant (X^2 = 83.36, df = 18, P < 0.001). Out of the 180 respondents interviewed mentioned that they most frequently use WEVs annually (30.6%), followed by daily (27.4%), weekly (25.5%) and monthly (16.6%), respectively in their area.

Generally, women 'interviewees (50.8%) were more knowledgeable on WEVs uses than men (49.2%). Also, youths (35.9%) and elders (34.3%) were more knowledgeable on identifying WEV's use than adults (29.8%) in their area, and this difference was statistically significant (X^2 = 70.495, df = 18, P < 0.001). Whereas, there were also statistically significant differences with level of household income (n = 161, small income) and (n = 20, large income) regarding the traditional knowledge on WEV uses (X^2 = 2.42, df = 9, P < 0.001), the former being more knowledgeable than the latter in the area. In our case, women (n = 82, 50.9%) had lower income compared to men (n = 79, 49.1%); though their differences were not statistically significant (P = 0.937).

In addition, a majority of the local community (86.6%) reported that the WEVs were more decreasing in supply than either increasing (7.8%) or remaining stable (5.6%); and their differences were statistically significant (X^2 = 16.72, df = 2, P < 0.001) and were difficult to access (n= 76, 42.0%, P <0.001). Also, a majority of the community (n = 181, 100%) agreed that the WEVs were improving their livelihood in the area.

Table 1. Wild edible vegetables species and their frequency of use by local communities

Species	Family	Frequency	Percent (%)	Domestic use (%)	Commercial use (%)	% Herbs	% Shrubs
Gynadropsis gynandra	Capparaceae	68	37.6	37.5	38.5	38.0	.0
Amaranthus hybridus	Amaranthaceae	38	21.0	21.4	15.4	21.2	.0
Solanum nigrum	Solanaceae	13	7.2	7.7	.0	7.3	.0
Corchorus tridens	Tiliaceae	32	17.7	17.9	15.4	17.9	.0
Oxygonum sinuatum	Polygonaceae	2	1.1	1.2	.0	1.1	.0
Brassica oleraceae var acephala	Brassicaceae	1	.6	.6	.0	.6	.0
Vigna unguiculata	Fabaceae	5	2.8	2.4	7.7	2.8	.0
Agaricus bisporus	Agaricaceae	1	.6	.0	7.7	.6	.0
Portulaca quadrifolia	Portulacaceae	19	10.5	10.1	15.4	10.6	.0
Capparis tumentosa	Capparaceae	2	1.1	1.2	.0	.0	100.0
Total		**181**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

DISCUSSION

Our findings revealed that 10 WEVs species were consumed by local communities in Serengeti reported. This is because the local people in the area use WEVs as they contribute to their food security and health as well as having nutrient values. In addition, according to Duguma (2020), WEVs are also an important to local communities of the Serengeti probably because as they are source of vitamins, fibers, minerals, fatty acids and sometimes they have medicinal value. This finding is similar to Nath (2015) who reported that about 75 wild food plants species used by various communities of Western Assam (a country which serves as a major gateway to the northeastern corner of India) from time immemorial and were also important in many indigenous communities around the world. Local communities consumed those plants or plant parts after either boiling or frying or preparing curry or chutneys or as raw. Also, the study by Duguma (2020) revealed that WEVs are relevant to household food security and nutrition in some rural areas and are relied on to supplement the staple food, to fill seasonal food shortages, and to serve as emergency food during famine. Local communities around the Serengeti ecosystem use these WEVs as an accompaniment for their staple food including meat and milk as well as cereal based diets food crops such as maize (*Zea mays*), rice (*Oryza sativa*), wheat (*Triticum aestivum*), potato (*Solanum tuberosum*), soybean (*Glycine max*) cassava (*Manihot esculenta*) which grown in their areas. In addition, Konsam et al. (2016) reported that the use of wild plants as food is an integral part of the culture and tradition of many indigenous communities around the world. Moreover, previous study also revealed that a large section of the rural population such as those of the Serengeti ecosystem meets their nutritional requirement through unconventional means, by consuming various wild plants and animal resources (Konsam et al., 2016).

Besides the recognized nutritional value of WEVs in the study area, WEVs are partly used for commercial purposes as most of the communities reported to sell more frequently *Gynadropsis gynandra, Amaranthus hybridus, Corchorus tridens and Portularca quadrifolia* in their area. This corroborate with finding of Duguma (2020) who reported that income and employment can be obtained from the sale of WEVs. This is agreed by Konsam et al. (2016) who reported that millions of people, mostly in developing countries, derive a substantial part of their subsistence and income from wild plant products. In addition, although WEVs provide staple food for indigenous people and serve as complementary food for non-indigenous people but they also offer an alternative source of income (Konsam et al., 2016).

Our finding also showed that women households in the Serengeti ecosystem possessed more traditional knowledge on WEVs including their identity and usage because women are more engaged in gathering and cooking of WEV than men (Bvenura & Sivakumar, 2017; Ghanimi et al., 2022; Tharmabalan, 2023). Also, the study by Konsam et al. (2016) observed that women household possessed more traditional knowledge about leafy vegetables including the identity of the species, usage, and mode of preparation compared to men. This could be due to their association with household chores such as cooking, marketing, and their home nurturing qualities (Powell et al., 2014; Konsam et al., 2016).

However, majority of the local communities (86.6%) in the Serengeti ecosystem reported that the WEVs were decreasing in supply and difficulty in accessing them probably because of overharvesting (Bvenura & Sivakumar, 2017; Duguma, 2020). In the same vein Powell et al. (2014), claimed that the decreased availability of WEVs is probably due to biodiversity loss and change in agricultural practice, government and development policies that ignore WEVs; loss of knowledge needed for gathering and preparation; and a general loss of cultural value for WEVs.

In this study it was found that communities with smaller income were more knowledgeable on WEVs they use than those with higher income in the area. This is because, WEVs are also important for many communities in rural villages and even those in urban areas, especially among the poor and marginalized (Duguma, 2020).

CONCLUSION AND RECOMMENDATIONS

This study concludes that though 10 WEVs species looks as a small number known by local communities to support food needs but some are still undocumented in Serengeti ecosystem. Therefore, we recommend more research for the documentation of the indigenous knowledge on WEVs through the involvement of local communities in order to ensure their sustainable use and management. Moreover, traditional knowledge of WEVs should be transmitted to future generations to obtain inexpensive food resource and improve their healthy status as previously had been reported that WEVs knowledge is gained early in life and increases with age (Konsam et al., 2016).

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INDIGENOUS KNOWLEDGE OF BEEKEEPERS ON HONEYBEES MORPHOLOGY AND BEHAVIOUR VARIATIONS IN THE SELECTED PARTS OF TANZANIA

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ABSTRACT

The present study aimed to investigate the diversity of honeybee based on morphology and behaviour using indigenous knowledge of Tanzanian beekeepers. Structured questionnaires were administered to 78 beekeepers of different age and experience in selected areas of Tanzania. This study reported existence of one to four 'types' of honeybees in different beekeeping areas. It was revealed that 42.3%, 53.8% and 44.9% of the beekeepers are aware of the decrease in honey storage, colony numbers, and sizes, respectively in Savannah and Mountainous ecological beekeeping zones. Further analysis revealed that 74.3% of the respondents are aware that shortage of forage influenced honeybee migration behaviour. However, the distance, direction and destination of the migratory colonies were not known by the beekeepers. In addition, contribution of various behaviours of the honeybees to the understanding of their variations was also not clearly known. While the beekeepers reported presence of different 'types' in their localities, there was no any evidence of change in the composition of 'types' in any part of the study area.

Keywords*:* beekeeping, comb building, defensive behaviour, food storage, ecological zone

INTRODUCTION

Indigenous knowledge (IK) is a complete body of knowledge, developed and maintained by people in rural areas with extended histories of interaction with the natural environment (Boven and Morohashi 2002), but contrasting with knowledge generated by formal education systems (Kajembe 2002). In beekeeping, IK application has been recorded in different parts of the world. Hussein (2001) documented the history of beekeeping including the indigenous technologies such as selection of suitable honeybee strains in North, East, North-East and West African countries. In Ethiopia, among the traditional beekeeping technologies, local queen cages are constructed from maize or sorghum stack for stopping swarming and absconding of honeybee colonies (Abebe *et al.* 2008).

In Tanzania, the beekeeping industry is dominated by traditional beekeepers who used indigenous knowledge (IK) in practices. Over 95% of the Tanzanian beekeepers use traditional techniques and 90% of them are old men (Kihwele, 1994; Mmasa, 2007). According to Lalika and Machangu (2008) and Msemo (2013), the beekeepers have a wide IK, which is useful for their practices in the beekeeping industry. This knowledge includes selection of apiary sites with assurance of high hive occupancy, sites with dominance of bee fodder plants and awareness of the changing annual beekeeping calendar caused by environmental changes. Whereas some of the knowledge regarding beekeeping practices in Tanzania has been documented, awareness of the beekeepers on the diversity of the honeybees are still insignificant. Mngazija *et al.* (1994) Silas (1998) and Kawa (*pers. comm*) reports on the presence of four 'groups' of colony types for Zanzibar, Kilimanjaro and Mafia are not a sufficient representation of the country. Additionally, the report by Manyirizu (*pers. –comm*) on the co-existence of different honeybee subspecies is comparatively scant. Therefore, identification and documentation of the information on honeybee 'groups' and its use as foundation on which to build further development is necessary. It is for these facts that traditional knowledge of indigenous people is continuously becoming a key tool in various aspects including beekeeping (Swiderska *et al.* 2011).

This study aimed at investigation and documentation of IK and experience of the beekeepers in relation to the diversity of the honeybees; and other associated aspects of beekeeping in selected ecological areas of Tanzania. The objectives of this study included determination of variation of bee colonies within beekeeping ecological zones in terms of honeybee morphology and behaviour, and changes of bee colony sizes and number over time. The behaviour in question includes migration, defence and storage of bee products.

MATERIALS AND METHODS

Study Area

The study was carried out in Coastal areas, Savannah areas and Mountainous sites corresponding to three honeybee species population ecological regions available in Tanzania (Table 1; Fig.1). The honeybees were named in altitudinal ascending order from the Coast, which included Coastal bees *A. m. litorea* (found from sea level to 500m), Savannah *A. m. scutellata* (between 500 and 2000m) and Mountainous *A. m. monticola* (between 2400m and 3100m above sea leve) as designated by Smith (1961) and Ruttner (1988). According to Smith (1961) *A. m. monticola* are relatively larger and are very hard workers that forage at lower temperatures comparing to their neighbour *A. m. scutellata*, while conserving stores and cutting down brood rearing at onset of dearth period. On the other hand, *A. m. litorea* which are relatively smaller than *A.m. scutellata*, are hard workers but do not ease brood rearing in difficult times such as occurrence of dearth period or enemies.

Table 1. Districts and regions visited for data collection

Habitat	District	Region
Coastal (below 500m asl)	Lindi	Lindi
	Mafia	Pwani
	Rufiji	Pwani
	Mkuranga	Pwani
	Kisarawe	Pwani
	Pangani	Tanga
	Muheza	Tanga
	Morogoro	Morogoro
	Kyela	Mbeya
Savannah (500m-2000m asl)	Lindi	Lindi
	Muheza	Tanga
	Morogoro	Morogoro
	Same	Kilimanjaro
	Manyoni	Singida
	Arusha City	Arusha
	Arumeru	Arusha
Mountanous (above 2000m asl)	Arumeru	Arusha

Questionnaire Administration

Questionnaires were administered in beekeeping areas of selected districts, that is, Lindi Rural, Rufiji, Mkuranga, Kisarawe, Morogoro Rural, Pangani, Muheza, Same, Arusha, Manyoni and Kyela. The respondents were purposively selected by help of local beekeeping extension officers. The questionnaires were administered separately to each respondent (Plate 1). The information recorded were beekeepers' demography and experience, apiary site selection and diversity of the honeybees in the beekeepers' particular areas. Other information included; change of behaviour of honeybees, migratory pattern of the bees, various habitats, habitat status of honeybees and colony numbers and sizes. Generally, the interviews were geared towards determination of the diversity of honeybees and indicators of dynamics of the honeybee population in the beekeeper's local areas.

Data analysis

The questionnaire data were analysed through descriptive and statistical analyses including frequencies, percentages and cross tabulations for qualitative variables using IBM SPSS (Version 20).

RESULTS

Socio-demographic Structure of the Beekeepers

The information on the social-demographic structure of the 78 interviewed beekeepers is presented in Table 2. The beekeepers with age ranging from 21 to over 80 years were interviewed and majority were between 41 and 60 years of age. Majority of the respondents had primary education and below, while very few attended secondary education and beyond (Table 2). The results revealed that majority of the respondents are peasants and form the major economic activity. Beekeeping, pastoralism and employment in informal sector remains as side activities and contributes 19.2% of their income. Further results indicates that despite being a side activity, respondents revealed wide experience in beekeeping ranging from 5 to over 30 years

Table 2. Socio-demographic characteristics of the respondents

Particular	Category	Pesponse(%)
Age	21-40	20.5
	41-60	47.4
	61-80	30.8
	above 80	1.3
Education	Informal	38.5
	Primary	55.1
	Secondary	5.1
	Tertiary	1.3
Major occupation	Peasant	80.8
	Beekeeper	12.8
	Civil servant	2.6
	Pastoralist	2.6
	Other	1.3
Years engaged beekeeping	less than 5 years	14.1
	5-10 years	35.9
	11 - 30 years	28.2
	over 30 years	21.8

Experience of the beekeepers in relation to age group

Experiences of different age groups of beekeepers in beekeeping activities are presented in Fig. 2. The four categories of experience are those practiced for less than 5 years, followed by 5 to 10, 11 to 30 and above 30 years. The highest frequencies of experiences for all categories were found among the beekeepers with age between 41 and 60. The study revealed a beekeeper of 40 years that had practiced beekeeping for 30 years (Fig. 2).

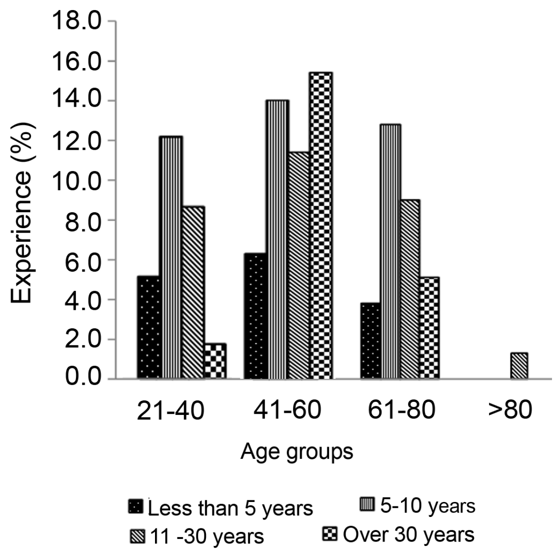

Figure 2. Experiences of different age groups of beekeepers in their beekeeping activities

Types of Hives and materials used for hive construction

The study observed that only 7.7% beekeepers used modern hives namely Tanzania Top Bar Hives (TTBH) and Tanzania Commercial Hives (TCH), while most of them (71.8%), with the remaining few mixing both modern and traditional (Table 3). Very few beekeepers (1.3%) used other hives made of materials such as calabashes and pots.

Locations of the apiaries

While most of the beekeepers sited their hives in the protected areas, others used home gardens, personal lands away from home and unprotected public lands (Table 4). The protected areas mostly used are village and national forest reserves, and other protected areas.

Indigenous knowledge on the diversity of honeybees

The majority (26.9%) of the beekeepers across the zones reported to have known two 'groups' of honeybees. Knowledges on one, three and four 'groups' were also reported, but in lesser percentages. While all the respondents from *A. m. monticola* geographical zone reported to have two 'groups', savannah zone was reported to have one, two, three and four; whereas coastal zone had one two and three.

Table 3. Hive types and materials commonly used for hive construction

Particulars	Category	Response (%)
Types of beehives	Modern	7.7
	Traditional	71.8
	Modern, trad.	19.2
	Others	1.3
Construction Materials	Timber	7.7
	Bark	15.4
	Log	51.3
	Timber, bark	5.1
	Timber, log	10.3
	Timber, log, bark	6.4
	Log and bark	1.3
	Others	2.6

Table 4. General location of the Apiary site belonging to the respondents

Apiary site	Responses (%)
Village forest/reserves	39.7
Home gardens	16.7
Private apiary	28.2
Other	15.4

Indigenous knowledge on honeybee behaviour changes

Most respondents reported that defence (83.3%), comb building pattern (91.2%) and migration (51.2%) behaviours did not change over time (Table 6). However, storage of honey have decreased to 42.3%, especially for the savannah and mountainous beekeeping zones. In addition, factors influencing migration behaviour reported in Table 7. Major factors influencing migration were forage (74.3%) and water (8.9%).

Table 5. Honey-bee 'groups' known to beekeepers in different beekeeeping ones

Zone	Taxa of honeybee reported				
	one	two	three	four	don't know
Coastal	8(10.3%)	10(12.8%)	6(7.7%)	0	0
Savannah	5(6.4%)	3(3.8%)	7(9.0%)	7(9.0%)	14(17.9%)
Mountainous	0	8(10.3%)	0	0	10(12.8%)

Table 6. Perception of the beekeepers on some honeybee behaviours over time

Behaviour	Category	Percentage of Response in Zones			
		Coastal	Savannah	Mountainous	Total
Defence	More defensive	1(1.3%)	1(1.3%)	0	2.6%
	Less defensive	3(3.8%)	2(2.6%)	0	6.4%
	No change	20(25.6%)	29(37.2%)	16(20.5%)	83.3%
	Don't know	0	4(5.1%)	2(2.6%)	7.7%
Comb building	Pattern changed	0	2(2.6%)	0	2.6%
	Pattern the same	23(29.5%)	31(39.7%)	17(22%)	91.2%
	Don't know	1(1.3%)	1(1.3%)	1(1.3%)	3.9%
Storage	Store more now	3(3.8%)	0	0	3.8%
	Store less now	7(9%)	16(20.5%)	10(12.8%)	42.3%
	Store the same	2(2.6%)	1(1.3%)	1(1.3%)	5.2%
	Don't know	12(15.4%)	19(24.4%)	7(9%)	48.8%
Migration	Migrate more now	9(11.5%)	12(15.4%)	0	26.9%
	Migrate less now	5(6.4%)	6(7.7%)	0	14.1%
	No difference	9(11.5%)	16(20.5%)	15(19.2%)	51.2%
	Don't know	0	2(2.6%)	3(3.8%)	6.4%

Table 7. Factors influencing migratory behaviour in honeybees

Category	Status	Responses		
		Coastal	Savannah	Mountainous
Colony number	Increased	15(19.2%)	4(5.1%)	2(2.6%)
	Decreased	4(5.1%)	29(37.2%)	9(11.5%)
	No difference	4(5.1%)	2(2.6%)	5(6.4%)
	Don't know	1(1.3%)	1(1.3%)	2(2.6%)
Colony Sizes	Increased	7(9%)	3(3.8%)	0
	Decreased	3(3.8%)	19(24.4%)	13(16.7%)
	No difference	13(16.7)	6(7.7%)	3(3.8%)
	Don't know	1(1.3%)	8(10.3%)	2(2.6%)

Current honeybee colony numbers and sizes

The status of the colony numbers and sizes are reported in Table 8. The respondent in the present study revealed a decrease in numbers and sizes of the honeybee colonies.

Table 8. Perception of beekeepers on the number and size of colonies in their respective areas over time

Category	Status	Responses		
		Coastal	Savannah	Mountainous
Colony number	Increased	15(19.2%)	4(5.1%)	2(2.6%)
	Decreased	4(5.1%)	29(37.2%)	9(11.5%)
	No difference	4(5.1%)	2(2.6%)	5(6.4%)
	Don't know	1(1.3%)	1(1.3%)	2(2.6%)
Colony Sizes	Increased	7(9%)	3(3.8%)	0
	Decreased	3(3.8%)	19(24.4%)	13(16.7%)
	No difference	13(16.7)	6(7.7%)	3(3.8%)
	Don't know	1(1.3%)	8(10.3%)	2(2.6%)

DISCUSSION

This study recorded 85.9% of the respondents to have more than five years' experience in beekeeping, implying confidence in knowledge, understanding of the honeybees and skills including preparation of beekeeping equipment, performing colony management, beekeeping calendar, honey harvesting and processing, and understanding of honeybee diversity and behaviours. In addition, 78.2% of the respondents were between 41 and 80 years of age, further indicating the presence of knowledge and experience. A study by Mmasa (2007) reported similar results in Hai District in Kilimanjaro region, Tanzania. This is an indication that the growth and success of beekeeping industry is a skilful activity which requires participation of people from different age groups. According to Kihwele (1994) and Namwata *et al.* (2013), traditional beekeeping is a skill and labour intensive job usually needs committed and experienced people. However, in the Miombo woodlands of south-central Africa, such skills are imparted to the young ones informally by elders through practice and experience (Fischer 1993). Although beekeepers of the age above 60 years in this study seem aged and weak, but they play a big role in transferring their IK to their young ones.

The low formal education possessed by the beekeepers in this study is a characteristic of many traditional beekeepers. Mmasa (2007) reported 60% of the interviewed in Hai district beekeepers to have attended only primary school education, while 3.4% and 3.3% having adult education and no formal education, respectively. These findings concur with reports by Fischer (1993) and Namwata *et al.* (2013) that the novice traditional beekeepers have to stay with their experienced elders for too long that they ignore formal education.

The use of traditional log and bark hives were more common than modern Tanzania Top Bar and Tanzania Commercial Hives, indicating the dominance of traditional practices with very little transformation to modern beekeeping. These reports are in agreement with the Tanzania Beekeeping Policy (URT, 1998) and findings by Lalika and Machangu (2008). The exclusive use of modern hives by very few respondents might be an indication of high prices of hives and lack of technology for their use.

On the other hand, the use of bark hives has decreased due to scarcity of the suitable trees and intensification of conservation efforts towards deforestation (Msemo 2013). Less use of bark hives has been accelerated by anthropogenic activities such as need for farming land, building materials, fuel-wood, charcoal and many more. This implies that, the use of log and bark hives has also contributed to the change of the vegetation cover and accelerated alteration of the ecological habitats of the honeybees.

Knowledge on plants for different purposes, including flowering plants that are good for honey (Fischer 1993), is a guide to the beekeepers on the selection of suitable apiary sites and subsequent beekeeping camps. In this study, for example, choice of apiaries in the village and government protected areas by the majority of the beekeepers indicated diminishing of the vegetation necessary for good apiary qualities in the private and public land. This implies that the choices indicated increased destruction of vegetation necessary for maintenance of the local ecological conditions in which, honeybee populations are also affected.

Establishment of apiaries in the protected/ reserved areas provides enough space for siting hives and abundant flowering plants for nectar and pollen production. Similarly honeybees pollinate the plants during pollen and nectar collection, hence increase overall biodiversity conservation (Agera, 2011). Therefore, approval for use of protected areas for beekeeping is appropriate for conservation both the honeybees and their habitat.

The investigation on the diversity of honeybees in the beekeepers' respective beekeeping areas indicated some variation in knowledge. The majority of the respondents indicated different knowledge of honeybee's groups. The mountainous zone reported two 'groups', of the honeybees in the area. This may be explained by overlapping and coexistence of *A. m. sculelatta* into *A. m. monticola* habitat, which might be explained by proximity between their habitats and modification of the montane forest habitat to attain characteristics favourable for the savannah honeybees. However, the two 'groups' reported within savannah and coastal habitats may not be the same in other areas of honeybee subspecies, given the differences in the habitat characteristic requirements. Equal response of the beekeepers in knowledge of three and four 'groups' within savannah honeybees may be an indication of either variation of knowledge about the honeybees or micro-ecological characteristic difference in the areas they occur. In either case more study is important. Of the coastal honeybees, the majority of the beekeepers knew of either one or two 'groups', except for the Rufiji where beekeepers knew of three. This may be influenced by presence of different vegetation types such as mangrove forests, coastal forest patches, coastal – miombo transitional forest and pure miombo forests close-by. All of the vegetation types may influence different characteristics such as behaviour and appearance to different colonies of honeybees.

The beekeepers in Rufiji and Savanna Arusha reported three and four 'groups', respectively, by names. Although reports by Smith (1961); Ruttner (1988); Meixner *et al*. (1989; 1994; 2000); Hepburn *et al.* (2000) and Gruber *et al*. (2013) have descriptions of subspecies based on scientific research, none of them are in support of the claims by the traditional beekeepers. In that case, the increases in claims of existence of different 'groups' within the same localities as reported by the traditional beekeepers should be honoured by follow-up taxonomic studies.

The fact that majority of the beekeepers have not observed changes in behaviours of honeybees despite change in environmental conditions in their respective areas indicate that either the stability of honeybee diversity has not been affected by environmental changes or the beekeepers have not been observant enough to note variations. Alternatively, the honeybees may have physiologically adjusted themselves to adopt new environmental conditions. The adjustment may be in agreement with Le Conte and Navajas (2008) who reported that modifications of the honeybee's life-history traits are affected by ecological changes and genetic variability which give rise to the selection of development cycles suited to new environmental conditions. The claimed increase in migration behaviour in some areas is common in tropical honeybees, associated with duration and predictability of forage abundance and quality in the contrasting environments (Winston *et al.* 1981; Schneider and Blyther 1988, Rinderer *et al.* 1993). However, the migration reported by respondents in the study areas may be a reaction towards changes in incidences of poor forage and the alternative forage abundant sites (Seeley 1983) caused by vegetation abundancy changes in the areas. As a result, ecological boundaries surrounding the honeybee subspecies may change, thereby allowing movement between or among different population areas that may lead to crossbreeding among them. However, migratory pattern of the honeybees of Tanzania has not been determined. In addition, in honeybees of Tanzania, just like the other honeybees of the tropics, the possibility of presence of genetic factors underlying the tendency of different colonies to migrate has not been established (Schneider and McNally 1992). In addition, the ability of the protected areas to remain as refuge for colonies seeking forage, water and natural nest while the unprotected areas are continuously destructed might be the driving force towards mixing and breeding between and among honeybee populations.

The reported general increase in natural nest sites especially in the protected areas is a result of reduction in the general natural vegetation outside protected areas, causing all the available colonies to concentrate in protected areas such as game reserves, forest reserves and mangrove forests. In this case, while colony numbers per area increase, production per colony decreases, due to the population exceeding carrying capacities of the areas and associated competition for the resources. However, the increase in natural nests in the investigated areas does not necessarily compensate for the general colony decrease.

Also, beekeepers reported reduction in both number and size of the honeybee colonies in unprotected area which might be attributed to reduction in general number of the natural nests and amount of forage for the bees, leading the surviving colonies to maintain the number of bees that can be supported by the available forage.

CONCLUSION AND RECOMMENDATION

The study revealed that Beekeepers are aware of the diversity of honeybees in different parts of their study area and from the beekeeper's perspective, there has not been a recent change of the honeybee diversity in their areas. Based on the observations above, taxonomic study of the honeybees to address the varying 'groups' in different ecological zones is required and due to evidence of occurrence of different groups of bees in the same ecological zone, further study for more investigation of overlapping is required.

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EFFECTS OF LIVE WILD ANIMALS TRADE BAN ON LOCAL COMMUNITIES LIVELIHOOD ADJACENT TO NILO NATURE FOREST RESERVE, TANZANIA

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ABSTRACT

Globally, Live Wild Animals Trade Ban (LWATB) has been developed and enforced as a principal conservation tool for safeguarding wild populations. In, Tanzania LWATB has been imposed temporarily by the government since March 2016 due to a breach of Wildlife Conservation Act No. 5 of 2009 by some of the actors. Subsequently, the government is currently planning to impose a total ban. However, the effects of LWATB on local communities' livelihood are less known. This study was intended to assess the effects of LWATB on the local communities' livelihood adjacent to Nilo Nature Forest Reserve (NNFR) in the East Usambara Mountains. Household questionnaires and key informant interviews were used for data collection. Descriptive and inferential statistics such as One way ANOVA, Turkey multiple comparison of means and paired t-test were employed. The study reveals that income accrued from Live Wild Animal Trade (LWAT) per year among the sampled six villages were statistically significant differences ($p < 0.05$). Furthermore, the Live Wild Animal trade (LWAT) before ban annually contributed about Tanzania shillings TZS 709,057,400/= (78.7%) of total income to local communities, whereas other Income Generating Activities (IGAs) after the ban contributed (TZS) 192,455,000/= (21.3%). Ultimately, LWATB has reduced local communities' income. We recommend that the government should uplift the ban on non-threatened species and facilitate local community initiatives conduct the trade sustainably.

Keywords: Live wild animal trade, income, income generating activities

INTRODUCTION

Live Wild Animals Trade (LWAT) refers to any sale or exchange by people of live wild animal species that are derived from their natural environment or raised under controlled conditions (Leader-Williams, 2000; TRAFFIC, 2008). The supply chain of this trade include exporters, middlemen, and local collectors (Rabemananjara et al. 2008). This is a growing trade (Roe et al. 2002, Baker et al. 2013, Bush et al. 2014, Harrington 2015) that is regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and specific countries' rules (CITES 2016, Janine and Pablo 2018). Globally, more than 5, 500 animal species are traded, its worth estimated to 300 billion US dollars per year (Conversation Africa 2020). The trade is dominated by birds, reptiles, and ornamental fish (Roe at el. 2002, Green et al. 2020). About 11,569,796 individual Live Wild Animals (LWAs), representing 1,316 various species were exported from 189 different countries between 2012 and 2016 (CITES 2017). This trade provide income to local communities (Rivalan et al. 2007, Baker et al. 2013, Biggs et al. 2016 and Robinson et al. 2018)enabling them to support their livelihoods (Neumann and Hirsh 2000, Roe 2008, Cawthorn and Hoffman 2015, Cooney et al. 2015, Coad et al. 2019).

Between 2006 and 2015, Tanzania was the largest exporter of live wild animals in East Africa, with an export of about 2,091 birds, 57,567 reptiles and 655 mammals annually (Outhwaite and Brown 2018). Majority of the LWAs from Tanzania are exported to the United States of America (USA) and Europe for pets and ornaments (Eurostat 2015). However, in 2001, the European Union (EU) imposed a temporary ban on the import of 15 bird and reptile species from Tanzania, because they were threatened species (Roe *et al*. 2020).

In Tanzania, LWAT was famous in East Usambara Mountains. It involved trade of snakes, beetles, chameleons, and birds (Roe *et al.* 2002, Milledge *et al.* 2003). Between 2009 and 2013, the Wildlife Division (WD) of Tanzania earned about 1 billion Tanzanian shillings from LWAs trade (WD, 2013a). Before the ban this trade created job opportunities for local communities and provided income that supported their livelihood (Roe *et al.* 2002, Milledge *et al*. 2003, Roe *et al*. 2020).

A wildlife trade ban intends to prohibit the commercial trade in wild animals, parts and/or derivatives (Santos *et al.* 2011), to safeguard wildlife populations (Challender *et al.* 2015, CITES 2016). In 1994/95, CITES banned trade for Fischer's turaco and Brown-headed parrot (*Poicephalus cryptoxanthus*) from East Usambara Mountains because of being threatened with extinction (Roe *et al*. 2002, Milledge *et al.* 2003). On other hand, a ban on LWAs trade could affect local community income (Roe *et al.* 2002, Abdullah *et al.* 2011, MacMillan and Nguyen 2014, Cooney *et al.* 2015).

In March 2016, Tanzania imposed temporary Live Wild Animals Trade Ban (LWATB) for three years due to a breach of the Wildlife Conservation Act (WCA) No. 5 of 2009 by some companies which exported live wild animals illegally (URT 2016). Currently, the government of Tanzania intends to impose a total ban on the export of LWAs for conservation purposes (URT 2019). Moreover, the ban on trade implied loss of national revenue of about TZS 1.83 billion per year that was used in provision of social services such as water, health and education (URT 2018). However, some local communities perceive the ban on LWAs trade have reduced their income (Roe *et al*. 2002, Milledge *et al.* 2003, Roe *et al*. 2020). Before the ban, local communities adjacent to Nilo Nature Forest Reserve (NNFR) in East Usambara Mountains were famous in LWAT. However, there is limited information regarding the effects of LWATB on local communities' livelihood. This study is going to ascertain the effects of ban in order to provide useful information for guiding decision makers, including the Ministry of Natural Resources and Tourism (MNRT) and CITES, on making right decisions balancing between conservation and local community livelihood through sustainable LWAT.

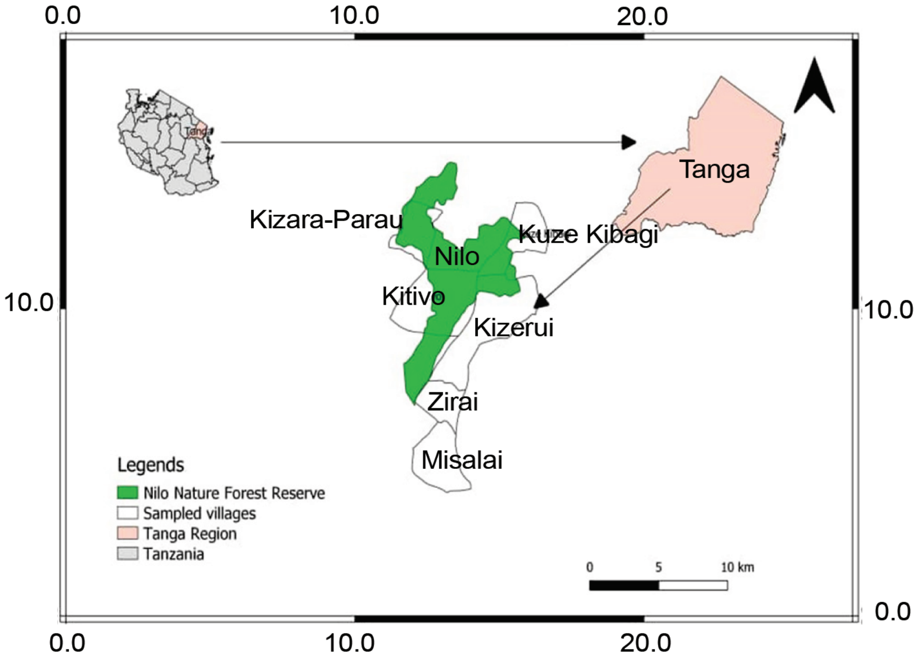

Figure 1. Six villages practiced live wild animals trade (Source: Said ,2021(unpublished))

MATERIALS AND METHODS

Study area

Our study was conducted in six villages adjacent to NNFR that were famous in LWAT before the ban. NNFR is the land of higher biodiversity and endemic flora and fauna in the East Usambara Mountains (URT 2020). Six villages were used for data collection namely Misalai, Zirai, Kizerui, Kitivo, Kizara, and Kuzekibago, which are located in the North West of the East Usambara Mountains between S 04° 50' – 59' and E 038° 37' – 41' (Fig.1); and fall under the jurisdiction of Muheza, Korogwe, and Mkinga districts, in Tanga Region (URT 2007).

Sampling approach

We used four sampling approaches including purposive, snowball, random and simple sampling. Purposive sampling was used to select six out 17 villages that were mostly involved in LWAT, based on information provided by legal authorities from Muheza, Korogwe and Mkinga districts. Also, using the same approach, 15 key informants were selected based on their knowledge and exposure to LWAT activities in the study area as advised in Kaswamila (2006). Snowball sampling procedure was used to locate unrecognized respondents in three villages i.e., Misalai (20 respondents), Zirai (40), and Kuzekibago (40) where most villagers were worried about providing information since some village members were apprehended as suspects of poaching incidences. Snowball household sampling has been used in villages that experience difficult in identifying local collectors of LWAs (Robinson *et al*. 2018).

Simple random procedure was applied to select recognized respondents (households) in the other three villages of Kizerui (50 respondents), Kizara (50), and Kitivo (50) where their names were prepared in the village offices. Simple household sampling was applied in the village that identified people who were engaged in the LWAT (Robinson *et al*. 2018). A total of 250 respondents were chosen to participate in this study, according to Kumar (2005), a sample size of 80 cases and above is suitable for rigorous statistical analysis.

Data collection

Data were collected based on Socio-economic included households income generating activities and demographic characteristics (age, sex, ethnic, marital status and education level). It collected between March and April, 2021, once in time to represent a cross-sectional research design (Olsen 2004). Both qualitative and quantitative data were collected as part of primary data; a semi-structured questionnaire containing both closed and open-ended questions was used. The household survey questionnaire included: - species, price per species, and number of species per order, number of order per week / month and per annual income. Additionally, key informants guide was used to supplement additional information to the collected data. Secondary data concern income generated before and after LWATB were collected from village governments and district council offices used to enrich the findings from the primary data.

Data analysis

Descriptive analysis was used to analyze income accrued from LWAT per year before the ban, the uses of income accrued from the LWAT before the ban; and as well as to compare income accrued from the LWAT to other Income Generating Activities (IGAs) per year after LWATB in the six sampled villages. Data were tested for Normality using Shapiro Wilk test (test statistics) (Hanusz *et al*. 2016). Then One Way ANOVA was used to test for differences in total income accrued by those six villages from the LWAT before ban .Tukey multiple comparisons of means was used to compare whether there was significant difference in the total income accrued from the LWAT before the ban among the sampled six villages. Lastly, paired t-test was applied to test whether there was statistically significant difference between total income accrued from the LWAT before the ban and other IGAs after the ban per year in the sampled six villages (Hedberg and Ayers 2015). Qualitative data from key informants were analyzed by using content analysis (Krippendorff 2019).

RESULTS

Income accrued from LWAT per year before the ban

Results show that across the six villages, LWAT was mostly for the nine species namely Usambara bush viper (*Atheris ceratophora*), chameleons (*Bradypodion fischeri* and *Triceros deremensis*), frogs (*Hyperolius argus*, *Hyperolius viridiflavus* and *Hyperolius spinigularis*), and beetles (*Megalorrhina harissi*, *Eudicella euthalia*, and *Argyorphegges kolbei*) (Plate 1).

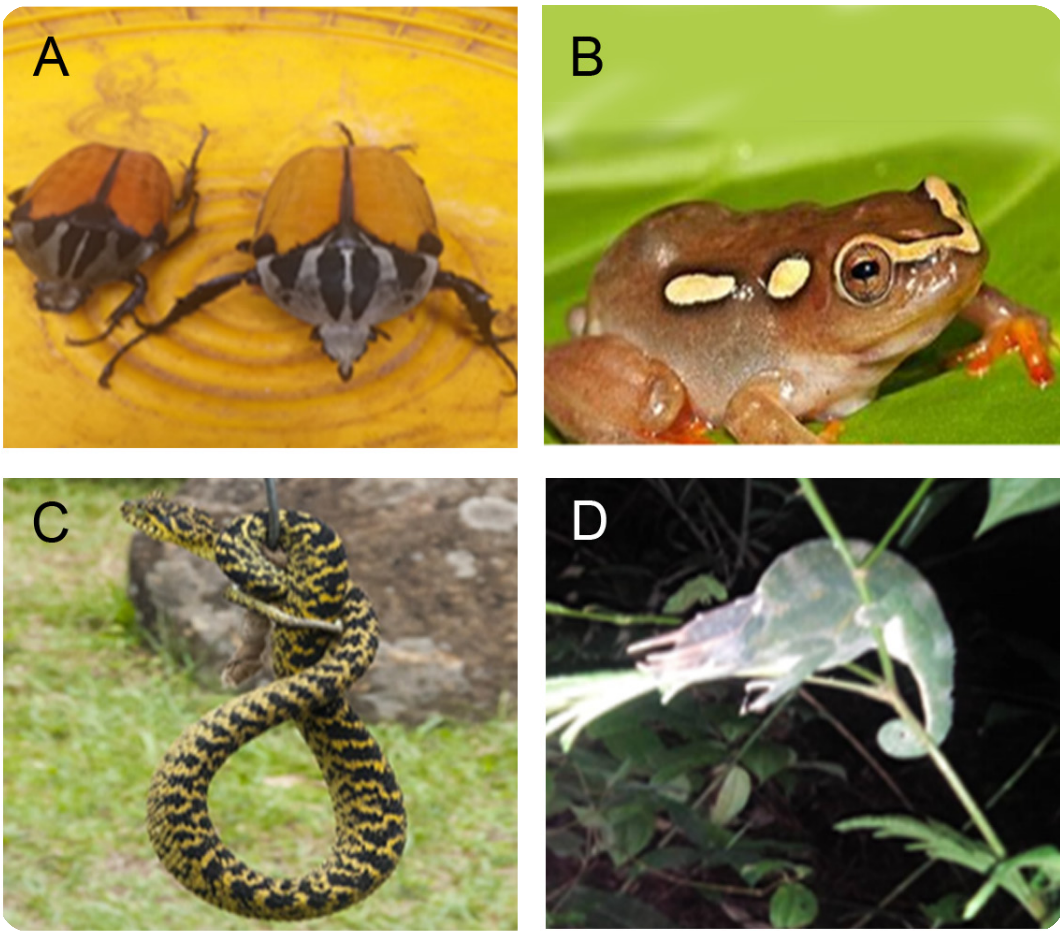

Plate 1. Some of the traded species in the six villages adjacent to Nilo Nature Forest Reserve: Kolbei beetle (*Argyorphegges kolbei*)(A), Reed frog (*Hyperolius viridiflavus)* (B), Usambara bush viper (*Atheris ceratophora*) (C), Three horned chameleon (*Chamaeleo deremensis*) (D)

Our results are consistent with Roe *et al*. (2002) and Roe *et al*. (2020), who have reported that snakes, beetles, chameleons, and frogs are among species involved in LWAT in Tanzania, because were common in the wild and were highly demand. One of the key informants stated in support of the above findings:

> *"The most traded species during the LWAT were: Nune (beetles), Momma (Usambara bush vipers), frogs, and chameleons. These species were readily available in the wild and backyards, and easily contributed income to communities involved in the trade*"

The study's results indicate that; the traded species were snakes, beetles, chameleons, and frogs, probably their demand and price were higher as well as they plentiful in the NNFR, therefore these species were moving to the public lands adjacent to the nature forest in search of food, space, and cover, where local collectors captured them and sold to the middlemen.

About 70% of respondents revealed that trade in beetles were conducted on a large scale in the East Usambara Mountains because they were easily found in the wild and were of high demand to consumers as pets similar to Roe *et al*. (2002) and Eurostat (2015) who indicated that beetles were traded in high quantities to European and United States of America (USA) countries as pets. From the household questionnaires, beetle trade generated more income compared to the trade of other species per year. For example, beetles generated TZS 555,907,400/=, vipers generated TZS 96,790,000/=, chameleons TZS 52,710,000/=, and frogs TZS 3,650,000/= per year for the households before LWATB.

In total, incomes accrued from the LWAT before the ban were TZS 709,057,400/= per year, which were: - Misalai TZS 100,842,400/= with average income of TZS 5,042,120/= per year, Zirai TZS 130,190,000/= with average income of TZS 3,254,750/=, Kizerui TZS 91,530,000/= with average income of TZS 1,830,600/= per year, Kitivo TZS 99,485,000/= with average income of TZS 1,989,700/= per year, Kizara TZS 234,460,000/= with average income of TZS 4,689,200/= for household per year, and Kuzekibago TZS,52 550,000/= with average income of TZS 1,313,750/= per year as presented in Table 1.

Calculation was based on species, price per species, and number of species per order, number of order per week / month and per annual income the result shown that: -

These results support Roe *et al.* (2002), Milledge *et al.* (2003), Cooney *et al.* (2015) and Robinson *et al.* (2018), who reported that the LWAT provided the local communities with an extra income enabling them to meet their needs, especially during the off-harvest season. Likewise, a similar note to support these results was provided by a conservationist during the key informant interview who said that:

> *"LWAT was generating extra income which enhanced households' ability to meet their needs, particularly during the farming season when there was no income accrued from selling crops. Thus, LWATB reduces their capabilities to meet their needs. "*

Generally, these results imply that LWATB has affected and reduced local communities' ability to acquire their daily needs such as foods, clothes and medicines. The income for 99.9% of male respondents engaged in LWAT, was reduced hence unable to meet financial costs. The most affected households were from Misalai village, where household income was accrued more from LWAT compared to households from the other villages possibly due to its close proximity to business center (Muheza district) hence opportunity of selling LWAs in high price compared to the other selected villages.

Comparison of income generated from LWAT per year among the six villages

The income generated from LWAT differed significantly among the six villages (F = 29.826, df = 249, p = 0.000) (Appendix i). Similarly, Roe *et al*. (2002); Cooney *et al*. (2015) and Robinson *et al*. (2018) reported that rural communities in developing countries are mostly dependent on wildlife resources, and their income vary with proximity to the wildlife areas. Study by Biggs *et al.* (2016) also reported that local communities located close to wildlife areas participate more in wildlife uses than distant communities.

The above results were supported by one key informant during the key informant interview who said that: -

> *"Villages such as Kizara and Kizerui that are located close to NNFR were mostly engaged in LWAT before the ban and accrued more revenue compared to the other villages. However, some people who were engaged in that trade will be worried about providing information since they conducted it illegally. "*

Table 1. Income accrued from the LWAT per year before the ban

Village name	Respon-dents (n)	Vipers (TZS)	Chameleons (TZS)	Frogs (TZS)	Beetles (TZS)	Total (TZS)	Average income/ household/ year (TZS)
Misalai	20	31,190,000	26,680,000	3,650,000	39,322,400	**100,842,400**	**5,042,120**
Zirai	40	7,150,000	6,500,000	0	116,540,000	**130,190,000**	**3,254,750**
Kizerui	50	0	0	0	91,530,000	**91,530,000**	**1,830,600**
Kitivo	50	0	600,000	0	98,885,000	**99,485,000**	**1,989,700**
Kizara	50	55,950,000	18,230,000	0	160,280,000	**234,460,000**	**4,689,200**
Kuzekibago	40	2,500,000	700,000	0	49,350,000	**52,550,000**	**1,313,750**
Total	**250**	**96,790,000**	**52,710,000**	**3,650,000**	**555,907,400**	**709,057,400**	**18,120,120**

Source: Field data, 2020

Distance from NNFR influenced availability of traded species and income accrued from LWAT, reason could be that most wild animals search for extra food near to their habitats in order to maximize the energy intake and minimize energy expenditure for moving far away. Wild animals moves to the communities that are located close to wildlife areas for searching their needs and reducing energy uses (Roe *et al*. 2002, Cooney *et al*. 2015, Biggs *et al.*2016, Robinson *et al*. 2018).

Furthermore, the post hoc test results show that: -Misalai-Zirai, Misalai-Kizerui, Misalai-Kitivo, Misalai-Kuzekibago, Zirai-Kuzekibago, Kizerui-Kizara, Kitivo-Kizara, and Kuzekibago-Kizara had the highest statistically significant difference at (Sig. = 0.000), whereas Zirai-Kizerui and Zirai-Kizara had the higher statistically significant difference at (Sig. = 0.006) and Zirai-Kitivo had a statistically significant difference at (Sig. = 0.22), as shown in Appendix ii.

The villages located closer to each other had statistically significant differences of total income accrued from the trade per year before the ban, while the villages located far to each other had higher statistically significant difference. Therefore, difference in term of distance influenced presence of traded species as well as income accrued from the trade. Perhaps villages located closer to each other had less similar habitat characteristics that influence availability of various traded species, whereas village found far from each other had quite different habitat characteristics with a big difference in number of traded species.

Income accrued from the LWAT before the ban and other IGAs after the ban per year

Before the ban, LWAT was generated TZS 709,057,400/= with its average income of TZS 2,836,230/= for household per year, while after the ban other IGAs was generated TZS 192,455,000/=, and its average income was TZS 769,820/= for household per year, under the following activities: - subsistence farming that generated TZS 157,055,000/=, followed by livestock keeping TZS 32, 300,000/= and petty businesses that generated TZS 3,100,000/= at household level (Fig 2).

These results are consistent with Milledge *et al*. (2003), URT (2013) and Roe *et al.* (2020) who showed that about 80% of local communities living in Tanzania were engaged in other IGAs such as farming and livestock keeping. This implies that 99% of local communities living adjacent to NNFR are engaged in farming; particularly spice farming, possibly due to the presence of conducive environments, especially rainfall patterns of three seasons per year, fertile land and reliable market for their crops (TFCG 2017).

Furthermore, paired sample t-test analysis was applied to test whether there was a statistically significant difference between total income accrued from the LWAT before the ban and other IGAs after the ban per year, and the result indicated that there was a highly statistically significant difference in income accrued from the LWAT and other IGAs ($t=21.455$, $p = 0.0001$) (Appendix iii).

These results are in line with Robinson *et al*. (2018), who found that LWAT was a part-time trade but was more profitable and generated more income than other activities. However, these results contradict Roe (2008) and Roe *et al*. (2020), who found that LWAT supports livelihoods by providing a small income source during certain times of the year. The reason could be that the majority of people were engaged in LWAT as a part-time activity after finishing the most significant activity of farming that generated more income compared to LWAT, but based on the results of this study 80.4% of respondents who were engaged in LWAT before the ban had a farm size of below 2 acres. Thus, after the trade ban they did not enough area for other IGAs especially farming and livestock keeping.

Uses of income accrued from the LWAT before the ban

Results reveal that income accrued from LWAT before the ban was used by local communities to finance farming activities by 36.4%, buy food stuffs by 29.9%, and pay for medical expenses (20.3%), build/repair houses (12.2%) and pay school fees (1.7%) as presented in Table 2.

These results correspond with those of Cawthorn and Hoffman (2015) and Coad *et al*. (2019), who indicated that LWAT contributes to food security for millions of people in developing countries. Moreover, Roe, (2008), Neumann and Hirsch (2000) and Cooney *et al*. (2015) show that LWAT supports the livelihoods of local communities by providing an extra income, allowing them to encounter the financial costs of farming, schooling, medicine, and books.

On a similar note, the results above were supported by key informants, where a wildlife conservation expert was quoted saying:

> *"... LWATB has reduced income for local communities, mostly those engaged in LWAT before the ban. The income enabled them to pay for other services such as*

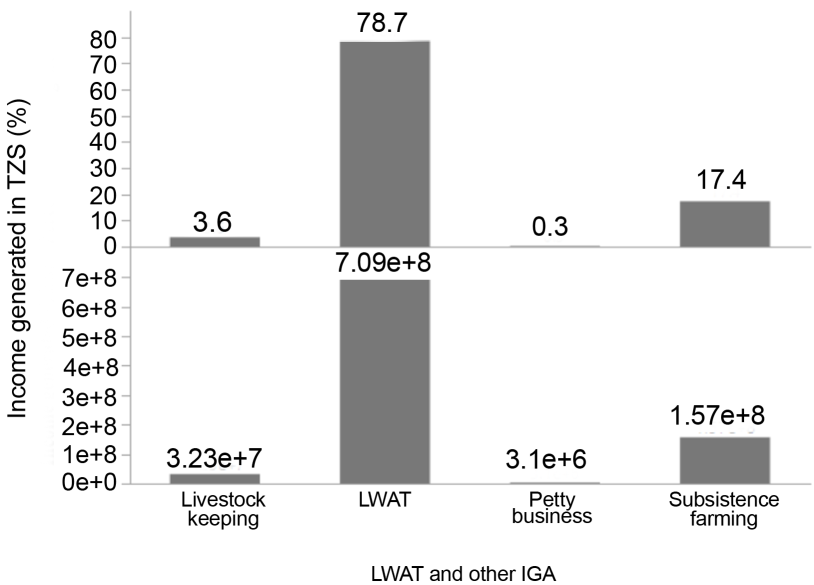

Figure 2. Income accrued from the LWAT before the ban and other IGAs after the ban per year

purchasing medicines, paying school fees and purchasing land and housing materials. Therefore, it would be better to uplift the trade ban for non-threatened species like beetles, chameleons, frogs, and toads and allow them to be traded sustainably based on their population."

These results imply that LWAT generated substantial income for households that were engaged in the trade adjacent to NNFR. Most of the income was used to facilitate farming activities rather than buy food stuffs. Reason could be that, most of them were also engaged in farming of food stuffs such as maize, rice, beans, and cassava. Therefore, after losing that income, they shifted and invested a lot of their time in spice farming in order to generate enough income to meet their financial needs. However, some of them have experienced crop raiding by wild animals especially primates possibly due to fact that farming in conducted in the reserve buffer zones.

CONCLUSIONS AND RECOMMENDATIONS

This study reveals that LWATB has reduced by 78.7% of the income of people who were engaging in LWAT, hence reducing their capacity to meet their basic needs, including financing medication and health services, school needs for children, investing in construction, rehabilitation of houses and buying food.

The Government of Tanzania through MNRT, need to facilitate local communities bordering NNFR to establish wild animals' captive facilities, including farms for traded species, as per the 2020 Wildlife Conservation (Management of Wildlife Captive Facilities) Regulations. Moreover, the government needs to reconsider uplifting the ban on non-threatened species which are common in the wild like Kolbei beetle (*Argyorphegges kolbei*) and Mesoline beetle (*Mecynorhina herissi*). Their trade should be enforced according to the Wildlife Conservation Act No. 5 of 2009 and associated regulations in order to guarantee sustainability.

Table 2. Uses of income generated from live wild animals trade

Choices	Responses		Percent of Cases
	N	%	
Paying school fees	9	1.7	3.6
Building/repairing a house	66	12.2	26.4
Paying for medical services	110	20.3	44
Buying foods	159	29.4	63.6
Financing farming activities	197	36.4	78.8
Total	**541**	**100**	**216.4**

Source: Field data, 2020

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APPENDICES

Appendix i:

One Way ANOVA: Comparison of income generated from LWAT before the ban per year among the six villages

Source of variation	Sum of Squares	f	Mean Square	F	Sig.
Between Groups	533637843460160	5	106727568692032	29.826	.000
Within Groups	873121476012000	244	3578366704967		
Total	**1406759319472160**	**249**			

Appendix ii: Tukey's post hoc pair-wise comparison test

(I) Villages	(J) Villages	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Higher Bound
Misalai	Zirai	2554570.000*	518051.641	.000	1066462.25	4042677.75
	Kizerui	3978720.000*	500485.434	.000	2541071.33	5416368.67
	Kitivo	3819620.000*	500485.434	.000	2381971.33	5257268.67
	Kuzekibago	4495570.000*	518051.641	.000	3007462.25	5983677.75
Zirai	Misalai	-2554570.000*	518051.641	.000	-4042677.75	-1066462.25
	Kizerui	1424150.000*	401281.076	.006	271466.70	2576833.30
	Kitivo	1265050.000*	401281.076	.022	112366.70	2417733.30
	Kuzekibago	1941000.000*	422987.394	.000	725965.11	3156034.89
Kizerui	Misalai	-3978720.000*	500485.434	.000	-5416368.67	-2541071.33
	Zirai	-1424150.000*	401281.076	.006	-2576833.30	-271466.70
	Kizara	-2858600.000*	378331.426	.000	-3945360.24	-1771839.76
Kitivo	Misalai	-3819620.000*	500485.434	.000	-5257268.67	-2381971.33
	Kizara	-2699500.000*	378331.426	.000	-3786260.24	-1612739.76
Kizara	Zirai	1434450.000*	401281.076	.006	281766.70	2587133.30
	Kizerui	2858600.000*	378331.426	.000	1771839.76	3945360.24
	Kitivo	2699500.000*	378331.426	.000	1612739.76	3786260.24
	Kuzekibago	3375450.000*	401281.076	.000	2222766.70	4528133.30
Kuzekibago	Misalai	-4495570.000*	518051.641	.000	-5983677.75	-3007462.25
	Zirai	-1941000.000*	422987.394	.000	-3156034.89	-725965.11
	Kizara	-3375450.000*	401281.076	.000	-4528133.30	-2222766.70

*. The mean difference is significant at the 0.05 level

Appendix iii: Paired samples t-test: Comparison of income generated from LWAT before the ban and other IGAs after the ban per year

Pair	Paired Differences			95% Confidence Interval		t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
LWAT–other IGAs	1.1975	0.88075	0.0558	1.0876	1.307	21.46	249	0.000

DOES HONEY COLOR HAVE ANY IMPLICATION FOR ANTIMICROBIAL ACTIVITY?

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ABSTRACT

This study aimed to verify whether the honey colour has any implication for the medicinal properties of honey. A total of 19 honey samples were collected from 14 purposefully selected high honey-producing areas involving 3 beekeepers per area to make a total of 42 beekeepers selected randomly. Wherever possible honey from stinging and stingless bees was collected. Honey colour was determined and antimicrobial activity was tested using three pathogenic bacteria (Staphylococcus aureus, Salmonella typhi, Escherichia coli) and one fungus (Candida albicans). Results showed that honey colour influenced honey sugar, water, and honey pH ($P<0.001$). There was no clear trend in honey pH referring to the honey colour, the dark-coloured honey was less acidic whereas water-white honey was more acidic ($P<0.05$). Water white honey was relatively more able to inhibit microbial growth followed by extra white, white, and light amber and lowest in the amber-coloured honey ($P<0.05$). Dark colour honey could not inhibit microbial growth of E. coli and S. aureus. Water white-coloured honey had the highest ability to inhibit bacterial and fungal growth. It was concluded that there is no relationship between honey colour and the ability of honey to inhibit pathogenic microbial growth.

Keywords: Stinging-bees, sting-less bees, medicinal properties

INTRODUCTION

Stinging honey bees (*Apis mellifera*) and stingless honey bees (*Trigona meliponini*) produce honey which is considered to be important for both treatment and nutritional purposes. Since 2100 BC ancient cultures used honey as medicine (Alvarez, *et al.*, 2010). Honey is characterized by its complex composition, which varies with the origin of the raw material as nectar or honeydew, bee species, climatic conditions, the available floral source and the storage conditions (Gheldof & Engeseth, 2003). Honey mainly consists of glucose and fructose but also contains amino acids, phenolic compounds, organic acids, vitamins, minerals, lipids, enzymes and other phytochemicals (Singh *et al*., 2012).

Various properties have been proposed to explain the effect of honey against bacterial growth; i) presence of hydrogen peroxide resulting from the action of the glucose oxidase enzyme (produced from hypopharyngeal glands of worker bees) on glucose in presence of oxygen inhibits microbial and fungal growth (Garcial *et al*., 1986); Wahdan, 1998; Molan, (1999) and Khan *et al*., 2007) ii) inherent physicochemical properties such as its high sugar content that can produce a high osmotic effect that dehydrates micro-organisms iii) the presence of diverse organic acids including gluconic acids which remarkably creates an acidic microenvironment (pH of 3–4.5) (Molan, 1992; Bogdanov *et al*., 1997), concentration varies considerably from one type of honey to another (White, 1978; Aparna & Rajalakshmj, 1999) and iv) non-peroxidic substances such as polyphenols which possess anti-microbial activity (Cabrera *et al*., 2006). These compounds vary depending on the plant species from which the bee gather their nectar (Cooper, 2007).

Honey colour has been related to the nutritive value of the honey, where deeply pigmented (darkly coloured) honey is superior in nutritive value to one of light colour and the darker the honey the higher the mineral content (Root, 1980). Mineral contents, total phenols and anti-oxidants have been reported to be positively related (Montenegro *et al*., 2006). Therefore, honey with deep colour is expected to have high anti-microbial activities, thus, the deeper the colour the honey has the broader the spectrum of anti-microbial, fungal and yeast (Kumar *et al*., 2010), higher total phenolic content and consequently higher anti-oxidant capacity (Montenegro *et al*., 2006). Antioxidant capacity is the ability and potential of honey in reducing oxidative reactions within food systems and human health. These oxidative reactions can cause adverse health effects such as chronic diseases and cancers (Gheldof *et al*., 2002). Compounds responsible to block these oxidative reactions are flavonoids, phenolic acids, ascorbic acid and organic acids as well as some enzymes including glucose oxidase and catalase (Gheldof *et al*., 2002). According to Manuela *et al*. (2006) polyphenols such as flavonoids and phenolic acids may function as antioxidants in honey. Not only could honey's antioxidants help to eliminate free radicals in the body but also be part of the nutrient supply for the growth of new tissues (Sham, 2010). However, USDA (2010) reported that there is no evidence that the beneficial effects of polyphenol-rich foods can be attributed to the antioxidant properties of these foods. The data for the antioxidant capacity of foods generated by *in vitro* (test-tube) methods cannot be extrapolated to *in vivo* (human) effects and the clinical trials to test the benefits of dietary antioxidants have produced mixed results.

The relationship between honey colour and antioxidants contained in honey and recent observation by USDA (2010) prompted the necessity of undertaking this study. Available studies in Tanzania have reported on the physicochemical properties of Tanzanian honey (Gidamis *et al*., 2004; Masoud, 2014). There is scanty information on the antimicrobial activities of Tanzanian honey in relationship to honey colour. Therefore, this study aimed to determine if there is a relationship between honey colour and the antimicrobial activity of Tanzania honey.

MATERIALS AND METHODS

Honey sampling procedure

A purposive sampling protocol was used to select high honey-producing areas where fourteen areas were selected, followed by simple random sampling that involved 3 beekeepers from each area. Honey was harvested directly from the beehives and bulked according to the area. When a beekeeper was keeping two types of honeybees both types of honey were collected, packaged in sterilized plastic bottles (330ml) then transported and stored at ambient temperature (25 ±2°C) at the laboratory of Micro-Biology at the Nelson Mandela Institute of Science & Technology, Arusha - Tanzania.

Antimicrobial sensitivity test

The antimicrobial sensitivity test of the honey samples was determined by the Agar Wells Diffusion method as described by Clinical Laboratory Standard Institute (2009). Where Mueller – Hinton Agar medium was used for antimicrobial susceptibility testing. The medium was prepared following the manufacturer's instructions. After autoclaving (121°C for 15 minutes) the medium was left to cool to 50°C. Then 25 ml per plate (15x100mm) was measured on a level pouring surface to a uniform depth of 4 mm and incubated in an incubator (35 ±2°C) for 24 hours.

The test organisms included bacteria (*Escherichia coli (*ATCC 25922), *Salmonella typhi (*ATCC14023) *and Staphylococcus aureus (*ATCC 25923*)* and fungus (*Candida albicans*-isolated from clinical samples), were streaked on to a non-inhibitory agar medium (broth agar) to obtain isolated colonies. After incubation at 35°C overnight, 4 to 5 colonies were picked and inoculated into broth (Mueller- Hinton broth) and incubated at 35°C for 24 hours. A sterile cotton swab was dipped into the suspension, pressed firmly against the inside wall of the tube just above the fluid level, and then streaked over the entire surface of the medium rotating the plate approximately 60 degrees after each application to ensure an even distribution of the inoculums, finally swabbed all around the edge of the agar surface. Small holes of 5 mm were made on the petri dishes with agar by using glass pastors and sterile loops, and then 100µl of the honey sample was placed in the agar holes using a sterile micropipette. The plates were inverted and incubated at 37 ±1°C for 24 hours for tested microorganisms. After the incubation period, the diameter of the zones of complete inhibition (including the diameter of the disk) was measured and recorded in millimetres. The measurements were made with a ruler on the undersurface of the plate without opening the lids.

Selected test pathogenic microorganisms

Various bacteria including *Escherichia Coli*, *Salmonella typhi*, *Staphylococcus aureus* and fungi such as *Candida albicans* are detrimental to health and food as they can cause diseases, food spoilage and food poisoning (Agros, 2005). *Escherichia coli* cause sickness, and food poisoning and are potential indicator organisms to test environmental hygiene for contamination (Feng *et al*., 2002). Bacteria such as *Salmonella typhi* cause illnesses such as typhoid fever, and food poisoning (Ryan & Ray, 2004). *Staphylococcus aureus* is a common cause of boils, impetigo, cellulitis, toxic shock syndrome and food poisoning (Levinson, 2010). In the same way, fungus such as *Candida albicans* is a causal agent of oral and genital infections in humans. All these pathogens, causing food-borne diseases have become a cause of major health concerns. Alternative use of natural food products such as honey with biological properties can help in the suppression and prevention of these pathogenic microorganisms.

Honey pH determination

The pH of honey samples was determined using a digital portable pH meter – JENWAY, UK 3305P in accordance with International Honey Commission (2009). In between the readings of different samples, the electrode was washed with distilled water and dried with tissue paper, inserted into prepared honey samples and recorded. The experiment was done in triplicates.

Honey's total sugar and water content

The honey sugar and water content were determined using a digital portable honey refractometer. In between the readings of different samples, the surface was washed with distilled water and dried with tissue paper before another honey sample was inserted.

Colour determination

Classification of honey colour was named and assigned a rank according to USDA Phoenix precision instrument Co. 3803 N. St. Phila. 40, PA, where samples of honey were placed in clean and clear McCartney bottles and observed against the colour.

Data analysis

Data obtained from antimicrobials in relation to honey colour were analyzed using SAS Version 16 software. Analysis of Variance (ANOVA) was used to determine the influence of the main independent variables, the factor influence was considered to be significant when $p<0.05$. Mean comparison between area and colour types was done using Duncan Multiple Range Test (DMRT) and results were presented as Mean ± SD.

RESULTS AND DISCUSSION

Effect of honey colour on sugar, water, pH, and microbial inhibition ability

Looking at the influence of honey colour on sugar, water, pH and microbial inhibition activity (Table 1) it is generally observed that a pronounced influence of colour was observed on sugar, water content and honey pH and less influenced the microbial activity of honey. More sugar was contained in extra white honey followed by water white, white and the least sugar content was observed in golden honey samples. There was no clear trend in honey pH referring to the honey colour, the dark-coloured honey was less acidic whereas water-white honey was more acidic. Looking at the ability of honey to inhibit microbial growth, water white honey was relatively more able to inhibit microbial growth followed by extra white, white, light amber and lowest in the amber coloured honey. This finding is opposite to many people notion who percirves normally that the darker the honey colour the more medicinal ability the honey possesses. It has been observed from this study that the antimicrobial activity of honey is positively related to the sugar content with a correlation coefficient of about 49% and negatively related to water and pH.

Simple sugar content, such as glucose in particular has been reported to play two important roles in antimicrobial growth. One is the facilitation of a high osmotic effect that can dehydrate microbial cells (Molan, 1992; Bogdanov *et al*. 1997) and two productions of gluconic acids which remarkably create an acidic microenvironment that prevents the growth of many micro-organisms (Cooper, 2007). However, results from this study show that sugar contained in honey can only account for about 49% of antimicrobial growth, thus, about 51% of antimicrobial inhibition is caused by other factors.

Other factors that influence honey's antimicrobial properties

Honey types

Figure 1 shows the comparative sugar, water contents, pH and ability to stinging and stingless bees to inhibit microbial growth. It was evident that the stinging bee honey was superior to stingless bee honey in sugar content and ability to inhibit microbial growth. There were no significant differences in pH between the two types of honey. The high sugar contained in stinging bee honey could be the reason for the honey to be better placed in the ability to inhibit microbial growth than stingless bee honey. Also, the fact that stingless bees don't mix pollen with honey whereas large bees mix honey and pollen to form what is so-called 'bee bread'. Manning (2000) revealed distinctive fatty acids profiles in pollen which are characteristically dominant in one or more fatty acids. The same author reported that pollens with high lipid concentrations are dominated by linoic, linolenic, myristic and dodecanoic acids which probably play a significant role in inhibiting the growth of the spore-forming bacterial such as *Paenibacillus larvae* (American foulbrood), *Melissococcus pluton* (European foulbrood) and other microbes that inhibit the brood combs of beehives. The higher water content of stingless honey ($P<0.05$) complies with the observation by Cortopassi *et al*. (2006) who reported a water content range of 25 to 35% in stingless honeybees. This factor of high water content reduces the ability of stingless honeybees to inhibit microbial growth. Furthermore, it contributes to its less cloying taste but also causes it to spoil more easily and if care is not taken stingless bee honey will spoil at room temperature (Cortopassi *et al*., 2006).

Referring to the colour of stinging and stingless bees honey it is clear from Table 3 that there was no clear pattern of a certain colour to inhibit microbial growth. The stinging bee honey that had white colour had the highest ability to inhibit microbial growth whereas the stingless bees honey that were amber in colour had the lowest ability to inhibit microbial growth.

The area where honey emanates

Table 4 shows the honey colour and the area where honey originates. Despite the dark colour of honey from Bukombe, the honey could not inhibit microbial growth of *E. coli* and *S. aureus*. Among all pathogenic microorganisms tested, *E. coli* was observed to be the bacteria whose growth could not be resisted by honey from Bukombe (extra white), Dodoma (sunflower – extra white), Inyonga (extra amber) and Nyakanazi (extra white). Comparing bacterial and fungi, *C. albican* activity was only observed in honey from Tabora (light amber), this means that fungi are more susceptible to honey than bacteria. The reason for bacteria being more resistant than fungi is probably because bacteria cells have a high spontaneous mutation rate (about 10 – 7 per cell division), this means that they can change their characteristics rapidly, thus, providing a greater variation on which natural selection can act, which helps them to survive in ever–changing environment (French et al., 2005). However, these results are different from that reported by Mohamad (2012) who tested the antimicrobial properties of stinging honey from Mauritius using bacteria (*Escherichia coli* and *Staphylococcus aureus)* and fungal (*Aspergillus niger* and *Candida albicans)* and observed that fungi were more resistant than the bacteria, this could probably be due to the concentration of honey used, where Mohamad (2012) diluted the honey used unlike in the present study no dilution was applied.

On the other hand, Gairo honey (water white) had a higher ability to inhibit both, bacterial and fungal growth, followed by honey from Morogoro (extra amber), Kisarawe (extra white), Itigi (white) and others (Table 4). Results in this study demonstrate that there is no relationship between honey colour and the ability of honey to inhibit pathogenic microbial growth.

However, other researchers had reported honey colour to be related to the nutritive value of the honey where deeply pigmented honey (darkly coloured) honey is superior in nutritive value to one of light colour and that the darker the honey the higher the mineral content (Root, 1980). Mineral contents, total phenols and anti-oxidants have been reported to be positively related (Montenegro *et al*., 2006). Antioxidants that naturally occur in honey may contribute to antioxidant capacity. Antioxidant capacity is the ability and potential of honey in reducing oxidative reactions within food systems and human health. These oxidative reactions can cause adverse health effects such as chronic diseases and cancers (Gheldof *et al*., 2002). Compounds responsible to block these oxidative reactions are flavonoids, phenolic acids, ascorbic acid and organic acids as well as some enzymes including glucose oxidase and catalase (Gheldof *et al*., 2002). According to Manuela *et al*., (2006) polyphenols such as flavonoids and phenolic acids may function as antioxidants in honey. Not only could honey's antioxidants help to eliminate free radicals in the body but also be part of the nutrient supply for the growth of new tissues (Sham, 2010). It has been demonstrated that honey is similar in antioxidant capacity to many fruits and vegetables on a fresh-weight basis, as measured by the assay of absorbance capacity of oxygen radicals (Gheldof and Engeseth 2003).

However, there is no evidence that the beneficial effects of polyphenol-rich foods can be attributed to the antioxidant properties of these foods (USDA, 2010). We know now that antioxidant molecules in food have a wide range of functions, many of which are unrelated to the ability to absorb free radicals. For these reasons the ORAC table, previously used has been withdrawn. This finding poses a situation where we cannot relate the anti-oxidant content of honey with antimicrobial properties.

The honey potency to pathogenic microbial growth has been reported by various scientists. Garcial *et al.,* (1986); Wahdan, (1998); Molan, (1999) and Khan *et al*., (2007) reported inhibition of pathogenic microbial growth from the presence of hydrogen peroxide resulting from the action of glucose oxidase enzyme produced from hypopharyngeal glands of workers bees on glucose in presence of oxygen that inhibits microbial and fungal growth. The presence of inherent physical-chemical properties such as high sugar content (about 80% w/w) that results in the high osmotic effect that dehydrates micro-organisms has been reported to inhibit microbial growth (Molan, 1992 and Bogdanov *et al.,* 1997). Aparna & Rajalashmj (1999); White (1978) suggested inhibition of microbial growth is due to the presence of diverse organic acids such as gluconic acids that remarkably creates an acidic micro-environment (pH 3 – 4.5) that prevents the growth of many micro-organisms. Apart from hydrogen peroxide as a factor that inhibits microbial growth, Cabrera *et al.*, (2006) elucidated inhibition of microbial growth to be due to the presence of non-peroxidic substances such as polyphenols which possess anti-microbial activity. Furthermore, Molan (1992) reported that in most honey antimicrobial growth depends on the enzymatic generation of hydrogen peroxide to a varying degree, but in some honey, there are additional phytochemical antibacterial factors. Cooper *et al.* (2002) elucidated that antimicrobial agents have been applied to wounds for 1000 years ago but many ancient remedies have been discontinued because the evidence to support their efficacy was anecdotal. He further, said that failure to identify botanical sources of honey used in many of the studies or to determine their antibacterial potency makes a comparison of reported sensitivity unreliable. Jones (2001) also reported that it is remarkable that ancient physicians were selective in the jars of honey they utilized in their remedies. All these observations reported exhibited that there is variation in medicinal contents depending on the area and type of vegetation where honey bees forage. This means that the antimicrobial composition depends on whether the plant foraged is a medicinal plant or not (Kakengi and Idani, 2018).

CONCLUSION

There is no relationship between honey antimicrobial activity and honey colour. Honey differs in antimicrobial properties due to differences in constitution and quality. These variations are attributed to the type of plant in which nectar and pollen are collected. Nectar and pollen from medicinal plants are far better to produce honey with a broader antimicrobial spectrum.

RECOMMENDATION

Stinging bee honey especially from areas with high medicinal plant is recommended for medicinal use of honey than the stingless bee honey. Stinging bee honey of any colour is recommended for medicinal purposes as long as is coming from nectar and pollen of medicinal plants.

ACKNOWLEDGEMENT

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Table 1. The effect of honey colour collected from various places in Tanzania (N=152) on the mean (±SE) sugar, water, pH and antimicrobial activity

Colour	**n**	**Property**			
		% Sugar	**% Water**	**pH**	**Inhibition zone (mm)**
Extra white	32	81.25[a]	17.38[e]	4.48[b]	18.75[b]
Water white	16	79.88[b]	19.50[d]	4.11[g]	26.25[a]
White	8	78.25[c]	19.75[d]	4.45[c]	18.13[bc]
Extra amber	24	77.0[d]	21.75[c]	4.41[d]	16.75[cd]
Light amber	16	76.0[e]	22.0[c]	4.42[d]	18.56[b]
Dark	24	75.42[f]	23.75[b]	4.56[a]	13.17[d]
Amber	8	75.0[f]	24.0[b]	4.42[d]	6.5[f]
Golden	24	72.63[g]	25.45[a]	4.32[f]	7.88[f]
Overall Mean		77.11	21.53	4.41	15.92
±SE		0.042	0.045	0.00003	0.044
Pr>F		***	***	***	*

Table 2. Correlation between honey antimicrobial activity and honey sugar, water and pH content

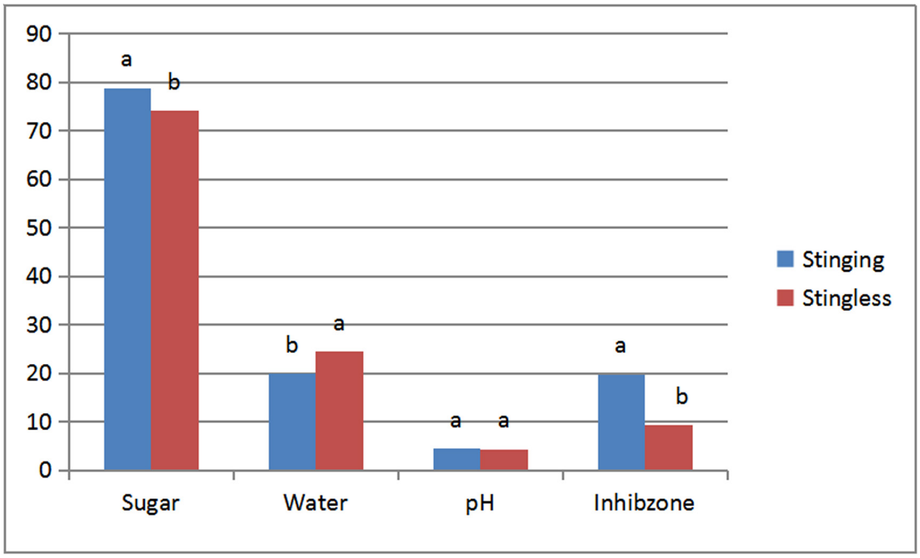
	Sugar	Water	pH
Water	-0.962 <0.0001		
pH	0.015 0.8527	0.0049 0.952	
Microbial activity	0.486 <0.0001	-0.4796 <0.0001	-0.0207 0.8003

Table 3. The influence of stinging and stingless honeybees' colour on the ability to inhibit microbial growth

Honey type	Colour	n	Property			
			%Sugar	% Water	pH	Inhibition zone (mm)
Stinging	Dark	8	75.50^{b}	24.25^{a}	4.83	17.25^{b}
Stinging	Extra amber	16	77.69^{b}	20.88^{d}	4.49	18.75^{b}
Stinging	Extra white	32	81.25^{a}	17.38^{e}	4.48	18.75^{b}
Stinging	Light amber	16	76.0^{b}	22.0^{c}	4.42	18.56^{b}
Stinging	Water white	16	79.88^{a}	19.50^{d}	4.11	26.25^{a}
Stinging	White	8	78.25^{ab}	19.75^{d}	4.45	18.13^{b}
Stingless	Amber	8	75.0^{b}	24.0^{b}	4.42	6.50^{d}
Stingless	Dark	16	75.38^{b}	23.50^{b}	4.42	11.13^{c}
Stingless	Extra amber	8	75.63^{b}	23.50^{b}	4.26	12.75^{c}
Stingless	Golden	24	72.63^{c}	25.46^{a}	4.32	7.88^{d}
	±SE		0.005	0.006	0.0001	0.050

Table 4. Effect of the area and honey colour on inhibition ability of various pathogenic bacteria

Area	Honey colour	Inhibition zone (mm)			
		C. albicans	***E. coli***	***S. aureus***	***S. typhi***
Bukombe	Dark	12.5^{c}	0.0	0.0	21.5^{c}
Bukombe	Extra white	16.5^{b}	0.0	31.5^{b}	23.5^{c}
Dodoma M	Dark	14.0^{c}	6.5^{g}	23.0^{d}	25.5^{b}
Dodoma S	Extra white	8.5^{e}	0.0	30.5^{b}	29.5^{a}
Dodoma U	Light amber	11.5^{dc}	19.0^{c}	23.5^{d}	30.5^{a}
Gairo	Water white	30.5^{a}	26.5^{a}	35.5^{a}	27.5^{b}
Inyonga	Extra amber	7.0^{e}	0.0	27.5^{c}	23.5^{c}
Itigi	Extra amber	11.5^{dc}	8.5^{f}	10.5^{f}	20.5^{c}
Itigi	White	10.5^{d}	10.5^{e}	22.5^{d}	29.0^{a}
Kisarawe	Water white	12.5^{dc}	22.5^{b}	29.5^{b}	25.5^{b}
Manyoni	Dark	11.5^{dc}	11.5^{e}	18.5^{e}	13.5^{d}
Manyoni	Extra white	14.5^{c}	22.0^{b}	31.5^{b}	25.5^{b}
Morogoro	Extra amber	16.5^{b}	15.5^{d}	30.5^{b}	29.5^{a}
Morogoro	Golden	10.5^{dc}	5.5^{g}	9.0^{f}	0.0
Nyakanazi	Extra white	10.5^{dc}	0.0	27.5^{c}	28.5^{a}
Nyakanazi	Golden	13.5^{c}	9.5^{f}	5.5^{g}	9.5^{e}
Sanya juu	Golden	$11.5d^{c}$	7.0^{g}	6.5^{g}	6.5^{e}
Tabora	Amber	$10.5d^{c}$	6.0^{g}	0.0	9.5^{e}
Tabora M	Light amber	0.0	19.5^{c}	25.5^{c}	19.0^{c}



Note: Means bearing different alphabets (a,b) on the same variable are different (P<0.05).

Figure 1. The comparative sugar, water contents, pH and ability of stinging and stingless bees' honey to inhibit microbial growth.

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IDENTIFICATION OF PLANT SOURCES OF POLLEN GRAINS IN HONEY FROM THE UNIVERSITY OF DODOMA APIARY

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ABSTRACT

Honeybees (Apis sp.) collect large quantities of pollen grains and nectar for making honey. The quality of honey depends mostly on plant sources of the pollen and nectar. The College of Natural and Mathematical Sciences at the University of Dodoma (UDOM) produces honey that is claimed to be of high quality. The current study investigated plant sources of pollen grains used by bees in making the honey at UDOM apiary, which is likely to be a key factor for its quality. Pollen grains from various flowering plants around the apiary were collected, observed under a light microscope, measured, photographed and a pollen atlas prepared. Honey from the apiary was observed under the microscope to identify the plant sources of contained pollen grains with reference to the prepared pollen atlas. Also, the relative abundancies of pollen grains from different plants were established. The results indicated only four plant species (or families) contributed most pollen in the honey. The diversity of pollen grains in the honey was lower than the diversity of flowering plants present around the apiary, suggesting that only a few flowering plants contributed most pollen. Identification, conservation and planting of plants that contribute most pollen in honey will ensure higher productivity of apiaries.

Keywords: Apiary, honey, honeybees, pollen, University of Dodoma

INTRODUCTION

Honeybees (*Apis mellifera*, family Apidae) are social insects in the order Hymenoptera. They form large perennial colonies in tree holes or other cavities and they readily accept artificial hives. Honeybees feed on nectar and pollen produced by flowering plants. Through foraging, honeybees provide one main ecosystem service, which is pollination. There is a mutualistic co-evolution between flowering plants and honeybees; honeybees need flowering plants as source of food (nectar and pollen) and flowering plants need honeybees for pollination.

During their foraging, honeybees collect large quantities of pollen grains and nectar which they bring to the hive for making honey and other bee products. For thousands of years man has cultured honeybees for obtaining honey. This has allowed man to better understand bee behaviour and ways of harnessing their pollination service, honey and other bee products. Honey is a common food item for hunter-gatherer societies (Marlowe *et al.* 2014). Nowadays bee-keeping is one among the major economic activities across the world. For example, it is estimated that there are about 57.1 million hives of *A. mellifera* managed by bee-keepers around the world (Crane 1990). In addition to the pollination services, commercial beekeepers provide honey, beeswax, royal jelly, propolis, pollen and other bee products.

Flowering plants are key sources of pollen and nectar for honeybees. Therefore, presence of flowering plants is a pre-requisite for developing a successful apiary (Kalpana 1997). Studies have indicated that the quality of honey and other bee products depends mostly on plant sources of the pollen and nectar (Balkanska *et al.* 2020). However, the species of flowering plants available in a given area are rarely considered during apiary establishment. Therefore, there is a need to study the pollen and nectar in honey from various areas to understand how the floral composition of honey affects its quality, foraging preferences of bees and the pollination services in an area.

Pollen grains from different species of flowering plants have specific shape, size and surface ornamentation which make it possible for identification of plant sources of pollen grains (Halbritter *et al.* 2018). Microscopic analysis is an established method to determine the source of pollen grains collected from bees, honey or bogs (Moore *et al.* 1991; Halbritter *et al.* 2018). Pollen analysis is important in determining past climates and vegetation of an area (Birks 1981; Scott 1989), foraging preferences of bees (Layek *et al.* 2020a) or even in forensic investigations (Jones & Jones 2001; Mildenhall *et al.* 2006).

The College of Natural and Mathematical Sciences at the University of Dodoma (UDOM) has an apiary with about 140 bee hives and produces honey that is claimed to be of high quality. However, botanical origin of the nectar and pollens used by bees in making the honey at UDOM apiary has not been investigated. Therefore, this study employed microscopic analysis to identify plant sources of pollen grains contained in honey from the UDOM apiary.

Objectives of the study

The main objective of this study was to identify plant sources of pollen grains used by bees in making honey at the UDOM apiary. The specific objectives were;

i. To collect and characterize pollens grains from different flowering plants at UDOM apiary.

ii. To collect, characterize and identify plant sources of pollen grains in honey from UDOM apiary.

iii. To determine relative proportions of pollen grains from different plants in honey from UDOM apiary.

METHODOLOGY

Study Area

This study was conducted in an apiary located at the College of Natural and Mathematical Science of University of Dodoma at $6^{0}10'23''$

south of the equator and 35^{0}44’31’’ east of the Greenwich Meridian. The apiary covers and area of approximately 0.6 km^{2} and has 140 top bar hives. The vegetation around the apiary consists of bushes of mostly the sickle bush *Dichrostachys cinerea* (locally called Mtunduru by the Gogo people), scattered *Acacia* spp., *Albizia* spp., *Grewia* spp. and other shrubs. During the wet season, the undergrowth is covered with various herbs

Figure 1. Map of the study area indicating sampling locations. Note that the apiary is located within the triangular area bordered by roads around the College of Natural and Mathematical Sciences of the University of Dodoma

and grasses mainly consisting of of Swamp marigold (*Bidens aristosa*), Black jack (*Bidens pilosa*), Sodom apple (*Solanum incanum*), the invasive Kongwa weed (*Astripomea hyoscyamoides*) among others.

Sampling design, data collection and processing

The study was carried in April 2021. Three 800m long transect lines running from East to West were established 200m apart at the UDOM apiary for sampling flowering plants (trees, shrubs, herbs, grasses). Circular plots of 10m radius were established after every 100m along the transects for collection of flowers from the blooming plants (Fig 2).

Pollen from flowers of each blooming species encountered at the sampling plots were collected in a clean envelope and taken to the laboratory for analysis. In the laboratory, a portion of the pollen from each plant species was mounted on a microscope slide to make reference slides. A cover slip was added and the edges sealed with clear nail polish. The reference slides were labelled with an ID of the plant species from which the pollen was collected. The slide was placed under a light microscope (Olympus BH2 fitted with AmScope 3 MP USB Microscope camera) and observed at 400x magnification to characterise the morphology and measure the diameter of the pollen grains from each plant species. Photographs of the pollen grains from each plant species were taken and a pollen atlas compiled for reference. Since the apiary and adjacent areas contain many species of flowering plants that differ widely in abundance and flowering phenology, reference slides of only the major flowering plants that were bloming at the time of data collection were considered.

Furthermore, raw honey harvested from the apiary during the study period was diluted with normal saline water, centrifuged and some pollen mounted on microscope slides. Following the same procedure used in analysing the pollen from flowers, the pollen grains in the honey were characterised by their morphometric features and compared with those of the reference slides to identify the plant species from which the honey pollen came from. Honey pollen that did not match any of the reference slides was considered to have come from "other plants".

Additionally, ten randomly selected regions of the microscope slides smeared with honey pollen were photographed and the number of different types of honey pollen grains on the photographs was counted to determine the relative contribution of different plants to pollen in the honey.

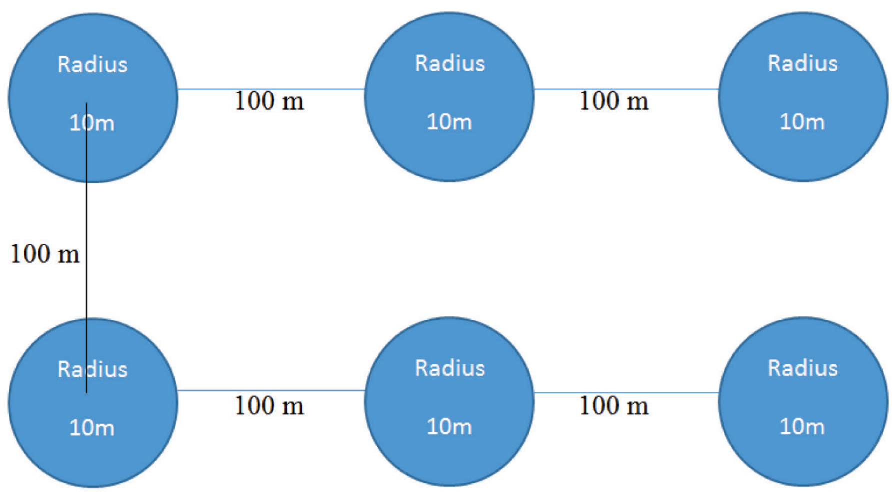

Figure 2. Layout of transects and sampling plots for collection of pollen from flowering plants at UDOM apiary

Data analysis

Data were analysed using Microsoft excel where summary statistics (means and ranges) were generated. Mean diameter of pollen grains were calculated from measurements of 30 randomly selected pollen grains. Then relative composition (percentage) of different pollen types in honey was calculated from mean numbers of pollen grains counted from 10 randomly selected regions of a microscope slide smeared with pollen from honey.

RESULTS

Characterization of pollen grains from flowering plants at UDOM apiary

Pollen grains were obtained from blooming 21 plant species. These plants included wild plants as well as cultivated crops that were planted around the College of Natural and Mathematical Sciences area for Bachelor students' research projects. Most sampled plants had spherical or oval pollen grains with average diameters ranging from 21.7 to 321.16 µm.

Table 1. Characterization of pollens from different flowering plants at UDOM apiary

SN	Plant species	Pollen characterization	Average diameter (µm)	Diameter range (µm)
1	*Albizia spp*	Large, Spherical, not Spined	28.8	25.1-31.0
2	Okra (*Abelmoschus esculentus*)	Spherical, long spine	139.48	136.4-147.9
3	Lemon (*Citrus limon*)	Spherical, not Spined	26.5	23.9-28.1
4	Sida acuta (*Sida acuta*)	Spherical, short spine	60.63	53.87 – 65.86
5	*Petunia* sp.	Spherical, not Spined	49.74	42.78 – 54.15
6	Mvunja shoka/sickle bush/ mtunduru (*Dichrostachys cinerea*)	Large oval not Spined	321.16	271.19-368.85
7	Black jack (*Bidens pilosa*)	Spherical, short spine	25.22	22.86 – 28.11
8	Swamp marigold (*Bidens aristosa*)	Spherical, short spine	26.34	22.13 - 29.56
9	Sodom apple (*Solanum incanum*)	Long, oval not spined	28.39	20.9 - 30.8
10	*Ipomea sp.* (Morning glory)	Spherical, short spine	71.0	66.3 - 75.2

SN	Plant species	Pollen characterization	Average diameter (µm)	Diameter range (µm)
11	*Astripomea spp* (climber)	Spherical, short spine	61.2	57.8 – 65.4
12	Pumpkin (*Curcubita pepo*)	Spherical, not Spined,smooth	117.0	106.6-122.7
13	Pomes granatum (*Punica granatum*)	Long, oval not spined	21.7	19.6 – 23.1
14	Papaya (*Carica papaya)*	Short, oval not spined	31.9	29.0 – 34.2
15	Leonotis (*Leonotis mollissima)*	Long, oval not spined	39.5	31.9 – 43.6
16	*Cleome hassleriana*	Larger spherical not spined	91.1	84.6 – 97.5
17	Sunflower (*Helianthus annuus*)	Spherical, long spined	33.6	31.9 – 34.8
18	Loranthus (*Loranthus* sp.)	Star-like shape	NA	NA
19	Gum Arabic tree (*Acacia senegal*)	short, oval not spined	135.3	122.3 – 150.5
20	*Senna singueana*	Long, oval not spined	36.2	32.0-41.1
21	Maize *Zea Mays*	Short, oval not spined	73.6	64.1 – 81.4

Identification of pollen grains in honey sample from UDOM apiary

Four types of pollen grains were recognised from the honey harvested from UDOM apiary (Fig. 3). The pollen grains labelled B were the most numerous followed by type D and the type A was the least numerous. Pollen type D typically occurred in clusters of four or five grains (i.e. tetrads or polyads) while the pollens type A, B and C were observed as single grains (i.e. monads).

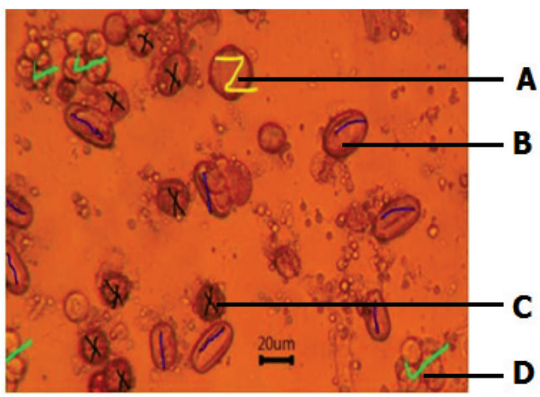

Figure 3. Different types of pollen grains observed in honey sample

Table 2. Characterization and identification of pollen grains in honey from UDOM apiary

SN.	Pollen label	Pollen character	Average diameter (um)	Plant source
1	A	Large, Spherical, Not Spined	28	*Albizia spp.*
2	B	Oval, long, not Spined	26.89	Unidentified
3	C	Spherical, Short-Spined	20.12	*Bidens aristosa*
4	D	Spherical, Not Spined, packed in 4, 5 or more units (polyads)	14.21	Unidentified

Relative proportions of pollen grains from different plant sources in honey from UDOM apiary

The pollen grains labelled B, D and C were the most numerous pollen types observed in the honey from UDOM apiary accounting for 42.2%, 33.4% and 22.7% of all pollen grains observed in the honey, respectively (Fig. 4). The pollen type A was the least numerous comprising only 1.7% of the pollen grains in honey.

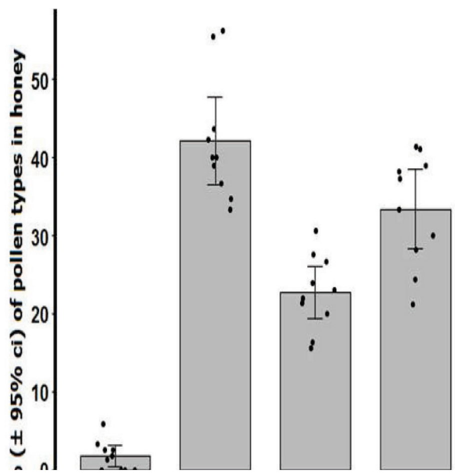

Figure 4. The relative composition of various pollen types in honey from UDOM apiary

DISCUSSION

Characterization of plant pollens from different plant species

The observed pollen grains were classified based on shape, pollen units and pollen texture. Additional characteristics like average diameter, length of spines (for spined pollen) was used for further characterization of the pollen grains. The pollen characteristics of twenty one flowering plants at UDOM apiary were obtained.

The shape and the external features of the pollen grains from different species are highly variable, and are often used to distinguish pollen grain produced by different species (Barth *et al.* 2009; Halbritter *et al.* 2018). In this study, the majority of the observed pollen grains were oval and spherical in shape suggesting that plants with such kinds of pollen gains are main bee flora at the UDOM apiary.

Mature pollen is shed in dispersal units that can be single grains, or clusters with multiple numbers of grains. Based on the number of units, the pollens were classified into monads, dyads and polyads. Monad pollens result when the post-meiotic products become separated and dispersal unit is a single pollen grain. When post-meiotic products become partly separated or remain permanently united, dyads (2 units) occur, a rare combination, or polyads (more than 2 units) (Halbritter *et al.* 2018). Majority of the observed pollen gains were monads.

Various surface ornamentations like spines and grooves were observed. These structures are closely related to the pollination mode of the pollens (Halbritter *et al.* 2018). From this study, pollen grains were classified into spined and non-spined based on surface ornamentation. The spined pollens were further classified into long, medium and short spined pollens. The spined pollen grains observed in this study were typically spherical in shape.

Identification of plant sources of pollen grains in honey sample from the UDOM apiary

Only four types of pollen grains were observed in honey sample collected from the UDOM apiary while there were more than 21 species of flowering plants around the apiary. These results show that pollen diversity does not reflect the actual diversity of flowering plants from the apiary (Table 1). This is because of the selective foraging nature of honeybees. That is, bees prefer certain plant species over others and the forage predominantly on a few plant species. Studies from other places have also observed that most of the pollen grains collected by bees come from relatively few plant species. For example, a study conducted in Menagesha Suba State Forest Ethiopia observed that only seven plant species contributed about three quarters of the pollen grains in honey although the area contained more than fifty eight plant species that were visited by honeybees (Admassu & Debissa 2009).

Furthermore, some of the pollen grains found in the honey samples did not correlate with any of the flowering plants around the apiary. This may be due to variation in flowering season among the different plant species, whereby some plants flower during dry season while others flower in the wet season. Since the study was carried out during the wet flowering season, some of the unidentified pollens may have been collected by the honeybees during the dry flowering season. Therefore, both flowering seasons contributed in the composition of the honey. Other factors like cross-apiary behavior of honeybees, long-distance foraging and the time lag between collection of pollen by bees until the time of harvesting of the honey may have affected the pollen composition and hence the failure to identify plants of origin of some pollen in the honey (Layek *et al.* 2020b).

Relative proportions of pollen grains from different plant sources in honey from CNMS apiary

Four key plant species - *Bidens aristosa, Albizia spp* and two unidentified plants contributed most pollen in the honey from CNMS apiary. The relative amounts of different pollen types harvested were affected by site. Colony preferences for different pollen types were noted. Relatively, more pollen was gathered from the flowering plants around the apiary. Among the two identified plant species, *Bidens aristosa* contributed 22.7%, while

Albizia spp contributed only 1.7% of the total pollen composition. This may be due to the fact that *B. aristosa* was one of the dominant flowering plants during the wet flowering season and was the most preferred foraging plant by honeybees during this season (Authors pers. observ. 2021). *Albizia* spp were few and scattered at the apiary but those that were blooming attracted many bees (Authors pers. observ. 2021).

The other two unidentified plant species contributed more pollen (775.55%) than the two identified plants (24.45%). These plant species may be the dominant flowering plants during the dry season which is longer than the wet season in Dodoma (Kassile 2013; Myeya 2021).

CONCLUSION AND RECOMMENDATION

Generally, the diversity of pollen grains in the honey was lower than the diversity of flowering plants presents at the apiary. The most important pollen types harvested by honeybees during this study were from four different plants, only two of which were identified. The relative amounts of the different pollen types harvested were likely affected by site, colony preferences and the interaction between climate and flowering season of plants. Pollen composition is important but is not the only factor determining the quality and quantity of honey. Other components like water and nectar availability are of crucial importance in honey production. Generally, in the area examined, the pollen composition of honey does not correlate with the diversity of flowering plants around the apiary. This may be limited by the scope of this study. It is thus recommended that;

i. Conservation and plantation of plants that contribute most pollen should be done to ensure higher productivity of the apiary.

ii. Further studies on various factors that affect the relative composition of pollens in the honey should be carried out.

iii. Additional studies on relationship between honey sugar concentration and its effect on pollen morphology should be conducted.

iv. Since honey composition varies among colonies and sites, considerations should be made for each hive when examining their relative compositions.

v. The study was conducted in one flowering season and cannot conclude on the fluctuations in annual pollen composition. Therefore all flowering season are important in the study.

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POISONING INCIDENCE OF ELEPHANT: A CASE REPORT FROM NGORONGORO CONSERVATION AREA

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ABSTRACT

African elephants are a keystone species or ecosystem engineers as they play a critical role in the ecosystems by shaping the landscape in many ways. During the dry season, they use their tusks and trunks to dig up dry riverbeds and create watering holes that is lurking below the surface and benefits other animals and birds. In February 2021, an elephant was found dead near Lodoare gate of Ngorongoro Conservation Area and the cause of death was uncertain at that time. There were no external injuries on the body though some parts were already scavenged. Postmortem examination was performed and significant pathological findings included yellow discoloration of subcutaneous tissues (jaundice), black discoloration of intestinal mucosa, hemorrhages on outer surface of the intestines, sloughing of inner wall of intestine, black discoloration of liver, kidneys, myocardium and lungs and cloudy dark fluid on cut surface of liver and lungs. These pathological findings lead to differential diagnosis such as poisoning, snake bite, electrocution and lightning strike. Sets of samples were collected and sent to the Government Chemist Laboratory Agency for confirmatory test. Toxicological tests confirmed presence of Strophanthidin, a cardiac glycoside derived from plants (Strophanthus species) that increases the output force of the heart muscles by acting on the cellular sodium-potassium ATPase pump which led to Calcium overload, diastolic dysfunction, arrythmias and ultimately heart failure and death. The use of strophanthidin to poison elephants opens doors for further investigation and intervention. Conservation education, community awareness and enhanced law enforcement will help to deter this kind of silent elephant killing.

Keywords*:* Elephants, human-wildlife conflict, Ngorongoro Conservation Area, Strophanthidin

INTRODUCTION

The Ngorongoro Conservation Area (NCA) is a multiple land use area and a unique system that permits people, livestock and wildlife to share their well protected habitat. Large wild animals mostly herbivores like elephants (*Loxodonta africana*), black rhinos (*Diceros bicornis*), buffaloes (*Syncerus caffer*), hippopotamus (*Hippopotamus amphibius*), giraffe (*Giraffa camelopardalis*), blue wildebeest (*Connochaetes taurinus*), plain zebra (*Equus quagga*), eland (*Taurotragi oryx*), grant (*Nanger granti*), Thomson gazelle (*Eudorcas thomsonii*) and waterbuck (*Kobus ellipsiprymnus*) are found in the area. Carnivores like lions (*Panthera leo*), leopards (*Panthera pardus*), spotted hyenas (*Crocuta crocuta*) among others are the predominant large carnivores in the area. Livestock like cattle (*Bos indicus*), goats (*Capri* spp.), sheep (*Ovis* spp.) and donkeys (*Equus africanus)* coexist with wildlife in Ngorongoro Conservation Area.

African elephants are a keystone species, as they play a critical role of shaping the landscape in the ecosystems in many ways. During the dry season, they use their trunks and tusks to dig up dry riverbeds and create watering holes or other spots to uncover water that is lurking below the surface. They often create very large holes by digging until they reach an adequate supply of water for them (WWF, 2021).

Both male and female African elephants have tusks, which are continuously growing teeth. Elephants eat roots, grasses, fruit, and bark, and they eat a lot of these things and can consume up to 300kg of forage and up to 200litres of water in a single day. These animals roam over great distances while foraging large quantities to sustain their massive bodies (AWF 2021).

As the human's population increases, there is also an increase in demand for area and resources for which the population extends to wild life areas and their territories are displaced. Agricultural expansion has constricted wildlife into smaller and remnant spaces (Sillero-Zubiri and Switzer, 2001). Human wildlife encounters with negative results such as crop damage, animal death, property damage, injuries to people and death, injuries to wild animals and the like are taking place in the protected areas such as National Parks, Game Reserves and in other conserved land. In fact, in the areas adjacent to protected areas which can accommodate great number of wild animals these scenarios are not uncommon (DeStephano and DeGraaf, 2003 Lamarque et al., 2009).

Human wildlife encounters with negative results such as crop damage, animal death, property damage, habitat destruction, injuries to people, injuries to wildlife and the like are increasingly taking place adjacent to protected areas such as National Parks, Game Reserves and other conserved land. It is commonly believed that, larger ungulates such as elephants, buffaloes, rhinos and hippopotamus, and large carnivores such as lions, leopards, cheetah (*Acinonyx jubatus*), spotted hyena, wild dog (*Lycaon pictus*) and crocodile (*Crocodylus niloticus*) are common wild animals responsible for most of the human-wildlife conflicts (Anon, 2005; Parker et al., 2007; Nyahongo and Røskaft 2011).

In Ngorongoro Conservation Area, pastoralists have comparatively been living in peace with wild animals (Biru et al., 2017). Traditionally they believe that wildlife is an inherent part of livestock and that separating them can spark off an instability in the ecosystem. Therefore, no matter how many incidences the wild animals cause to human or livestock, pastoralists tolerate and continue with co-existence (Mponzi et al., 2014). However, according to unpublished reports, when livestock are attacked by wild animals such as lion it is normally cornered and killed using traditional weapons such as machetes (sime) and spears. Whilst, in the adjacent villages where agricultural activities (maize, coffee and beans plantation) are conducted, when the wild animal (elephants, rhinos or buffaloes) raid crops, some villagers kill the animal using poisoned arrows. Therefore, the aim of this paper is to provide baseline information on the occurrence of poisoning of wild animals using plant extracts (strophanthidin) as an indicator for silent poaching or retaliatory killing which if we let it go uncontrolled will result in increased incidences. Also, standard operating procedure (SOP) is recommended in dealing with human-wildlife conflict.

MATERIALS AND METHODS

Investigation area

Ngorongoro Conservation Area has a size of 8,292 km^2 located in Ngorongoro District, Arusha Region. In the Northwest it adjoins the Serengeti National Park and, in the north, it borders with the Pololeti Game Reserve (PGR) and Piyaya ward of Loliondo Division, the southern and eastern boundaries are defined by rim of rift valley wall and nearby Karatu district villages. Common activities carried out in Ngorongoro Conservation Area (NCA) include pastoralism, natural and cultural resources conservation and tourism development. The districts adjacent to the NCA include Longido, Monduli, Meatu and Karatu. Main anthropogenic activities done in these villages are commercial agriculture (coffee and wheat plantations), small scale

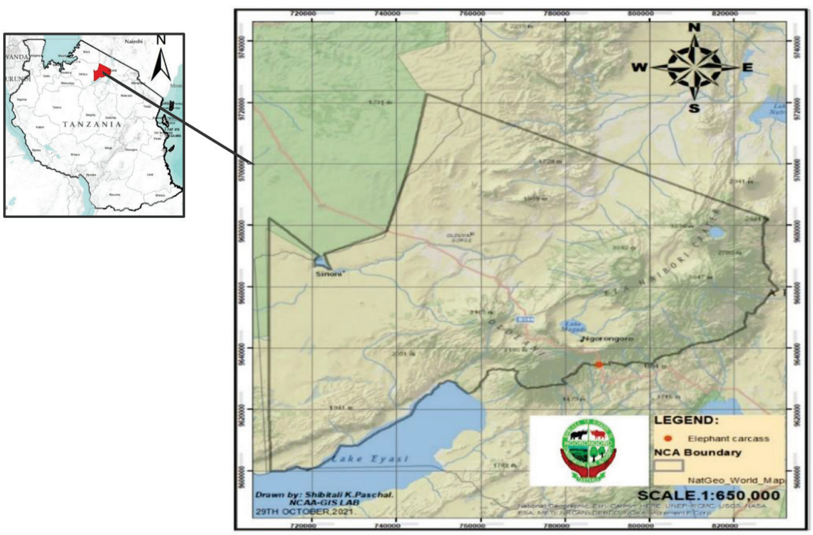

Figure 1. Location of poisoned elephant near the NCA Loduare entrance gate (red dot) and map of Tanzania to show the location of NCA

farming (maize, beans, onions and sunflower), and pastoralism.

History of the case

On 10th February, 2021, an elephant was found dead near Loduare gate and the cause of death was uncertain at that time. There were no external injuries on the body though some parts were scavenged. A team from Veterinary and protection unit joined to conduct the post-mortem examination.

Investigation process

Postmortem examination was carried out from 12:28PM to 15:30PM in a systematic manner. After a thorough examination of the carcass, the possibility of death due to some infectious disease, snake bite, or electrocution was ruled out. Anthrax was ruled out by conducting methylene blue test. Therefore, the death of this elephant was thought to be probably due to poisoning. The posture of the carcass and other signs (passage of fecal materials) on the vicinity indicated some signs of struggle before death. Thus, the death was not sudden. Pathological findings were noted and photographed appropriately and on 15th March 2021 sets of samples collected during postmortem were sent to the Government Chemist Laboratory Agency for confirmatory test.

Photo. Some pathological findings observed in internal organs (intestines, liver, heart, stomach) during postmortem examination

SIGNIFICANT FINDINGS

Postmortem findings

Findings included yellow colour of subcutaneous tissues (jaundice), black discolouration of intestine membrane, hemorrhagic lesions of intestines, sloughing of inner wall of intestines, black discolouration of liver, kidneys, myocardium and lungs, cloud black fluid on cut surface of liver and lungs.

Laboratory findings

Toxicological tests (high performance liquid chromatography-HPLC and electrospray ionization mass spectrometry-ESI MS) were carried out and confirmed that, the death of an elephant near Loduare gate was due to strophanthidin poisoning**.** This poison is extracted from plant known as *Strophanthus* which belong to Apocynaceae family. It is a flowering plant that is distributed in some area of tropical Africa, India and Asia. *Strophanthus gratus & S. kombe are commonly used* as cardiac-stimulant and in the treatment of snake bites (Glynn, 1964). *Strophanthus* contains cardiac alkaloid called strophanthidin a glycoside with similar mechanism of action as Digitalis, Ouabain and digitoxin (Glynn,1964 and Kanji at el., 2012). It inhibits the membrane protein sodium-potassium (Na+/ K+ ATPase) pump in heart muscle which can lead to calcium overload, diastolic dysfunction, arrythmias and lead to heart failure and death. Native African tribes use Strophantidin among other toxins as arrow poison. (Sjodin,1968).

DISCUSSION

In the laboratory, it was confirmed that the death of an elephant was caused by strophanthidin poisoning**.** This is cardiac glycoside that increases the output force of the heart muscles and increase its rate of contractions by acting on the cellular sodium-potassium ATPase pump which lead to Calcium overload, diastolic dysfunction, arrythmias and ultimately to heart failure and death (Kanji at el., 2012). Before this postmortem, one female black rhinoceros was found dead around the same zone from unknown cause, and the carcass was scavenged by hyenas before sample collection. However,

Photos: Show common strophanthus plants found in the tropical Africa,
Source: Tropical Plants Database (https://en.m.wikipedia.org)

strophanthidin was detected in faecal samples of a sick male rhino, which was in company with the dead rhino in the same zone where an elephant was confirmed to have died from the poison.

Following detection of poison in elephant tissues, the law enforcement team conducted an investigation involving the intelligence unit. The poison extract in powder form was impounded and several suspects were arrested in surrounding communities.

Strophanthidin is available locally as an extract from plants called *Strophanthus* which is used in some native African tribes as arrow poison and found in roots, seeds or leaves (Laidlaw.1909) and use of poisoned spears and arrows in elephant hunting has been recorded before. Strophanthidin can enter the body through ingestion of contaminated food materials or intramuscularly. It works as an inhibitor of sodium-potassium pump which has side effect on cardiac muscles in which increases sodium and cause an influx of calcium leading to increased muscular contractions (Riganti at el., 2011).

As human population increases and natural habitats decrease, people and wildlife competitions for resources increase over a limited land (NCAA, 2020). The outcome is often detrimental to people by losing their crops, livestock, property and sometime lives. On the other hand, retaliatory killing of wildlife some of which are in threatened or endangered status, like rhinos and elephants that come across crops fall victims of human killing using various mechanisms. Human-wildlife conflict is becoming severe and frequent nowadays as a result of human population growth, extension of infrastructures such as transport, industries and agricultural activities which lead to increased human encroachment on previously wildlife occupied areas (Dickman, 2010).

Dispersal of wild animals especially elephants and rhinos outside the protected areas pose security challenge to these animals. Due to factors mentioned above, elephants have been raiding crops in adjacent communities resulting into conflict with humans (Dickman, 2010). These conflicts sometimes lead to deliberate intentions of humans to kill wild animals in which some use poisons such as plant poisons like strophanthidin in revenge to the negative effects caused by the latter. However sometime this can be an indicator of silent poaching. Therefore, human-wildlife conflicts have been escalating due to the fact that, local people in communities feel that the values of wildlife are given higher priority over their own needs (Swanson, 2007). The conflict has important outcomes for local populations in several ways such as food security, safety and well-being, for the economy, and also for wildlife conservation.

Finally, this case report suggests further investigations on strophanthidin to know its origin, uses, distribution and susceptible species within the area. Empower community members who live adjacent to protected areas to recruit, train, and equip village game scouts (Karanth, 2002 and GoN. 2015). These game scouts will monitor wildlife and can prevent them from destroying crops, thereby preventing farmers from viewing them as pests. Therefore, research is needed to know and address the magnitude and complexities of conflicts. Game scouts are also instrumental in deterring poachers. Strengthening of security (protection unit) and intel unit to be proactive, will help to pin the illegal movement of people within the protected areas and will help to preempt the effect before it happens. Proactive conflict mitigation programs are needed, along with the installation of suitable barriers to prevent crop destruction and promotion of behavioral adjustments to the local community to minimize encounters and result in successful conservation and enhanced livelihoods.

CONCLUSION AND RECOMMENDATIONS

Conclusions

The vital basic needs for both humans and wildlife are food, water and shelter. When basic needs are at risk, conflicts arise. Humans meet losses in various forms like crop destruction, properties and even lives. Similarly, wildlife is also affected by the reciprocation that they face from people. This is the very forestate of human-wildlife conflict that has been stated in this report. Furthermore, as human population growth increases and climate change continues to defy the continuance of living condition of both wildlife and the humans, both will have to struggle with limited living spaces and water. Such conditions could facilitate further conflict.

Recommendations

Laboratory confirmation of strophanthidin is new finding which provide baseline information to the researchers to work on it to see the origin, distribution and species affected.

1. Emergency preparedness and rapid response measures should be further strengthened in all wildlife areas to ensure close monitoring of the situation with a view to making a rapid diagnosis to institute appropriate control measures.

2. Education awareness on conservation to the adjacent community, whereby this can be done as rapid response to the situation and improve community conservation services (ujirani mwema).

3. Tightening the security and intel unit to be proactive will help to deter the negative impacts of baiting wildlife with poisoning.

4. Establishment of standard operating procedure (SOP) is strongly recommended in dealing with human-wildlife conflicts.

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APPROACHES AND TECHNIQUES FOR MANAGING THE HUMAN-ELEPHANT CONFLICT IN WESTERN SERENGETI, TANZANIA

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ABSTRACT

Human-elephant conflict (HEC) is a ubiquitous feature between Ikorongo-Grumeti Game Reserves (IGGRs) management and the adjacent communities of Bunda and Serengeti Districts, in Mara Region. This study aimed to assess the emerging resources use conflicts and suggest appropriate approaches and techniques for effective mitigation of HEC in the area. Data collection involved direct observations, key informant interviews and household survey using questionnaires. The analysis was done using R, and SPSS computer softwares. Results revealed and recommended a number of non-conventional mitigation measures namely construction of trench (95.3%), electric fencing (92.7%), establishment of buffer zone management units (BZMUs) (92.7%), geo-fencing system (92.3%), Wireless Sensing Network (WSN) (85.3%), translocation of problem elephants (11.7%), and evacuation of people near PAs boundaries (22%) as HEC prevention and mitigation measures with long-term impacts. Generally, no single solution was found to be effective as different approaches need to be integrated to address the problem proactively. Hence, it is recommended that community involvement in decision-making and policy formulation be emphasized for effective implementation of proposed mitigation measures.

Keywords: Elephant, Human, Techniques, Western Serengeti

INTRODUCTION

Human-elephant conflict (HEC) marks one of the greatest challenges of conservation in many countries around the world (Burn *et al.*, 2011). Asian elephant for example (*Elephas maximus*), is one of the principal sources of human-wildlife conflict in some of Asian countries as they have consistent impact on the livelihoods of local populations (Nyhus and Tilson, 2004). In Indonesia, 12 elephants were reported to be poisoned to death by farm workers as they were trying to enter and feed on oil palm plantations. In China, in the mountainous area of Simao, near Xishuang Banna Nature Reserve, property damages and crop raiding by Asian elephants have been reported to be done by a group of about 19 to 24 elephants (Distefano, 2005; Chen *et al*., 2016).

In African countries such as Cameroon, Zimbabwe and Namibia, African elephants (*Loxodonta Africana*) were seen to be the most aggressive animals once they enter into communal lands compared to lions and other predators, as they attacked a large area and raided crops (Hedges and Gunaryadi, 2010; O'Connell-Rodwell *et al.,* 2000; Sarker and Røskaft, 2010). In particular, HEC affects humans socio-economically and culturally as people spend much of their time guarding crops in the fields while threatening survival of elephants through revenge (Archie and Chiyo, 2012; Fungo, 2011; Jadhav and Barua, 2012). In Kenya, 50 to 120 problematic elephants are shot dead by wildlife authorities each year as a measure to control them from killing human beings (Wanyingi, 2014). As a result, HEC together with other factors such as poaching and habitat degradation, have caused decline in African elephant population from around 3-5 million to between 470,000 and 690,000 in the last 100 years (WWF, 2014).

Human – Elephant interaction problems in Tanzania

Every year, Tanzania loses its elephants due to poaching, human-elephant conflict and habitat degradation (CITES, 2010). For example, a census survey conducted in 2009 across the six ecosystems namely Tarangire-Manyara, Serengeti, Selous-Mikumi, Ruaha-Rungwa, Katavi-Rukwa and Moyowosi-Kigosi covering 229,318 km^2 showed the elephant population fell from 142,788 in 2006 to 109,051 in 2009 (TAWIRI, 2010). In the past five years to 2014, Tanzania has lost 60% of its elephants, as the population fell from an estimated population of 109,051 in 2009 to about 43,330 elephants in 2014 (EIA, 2014; WildAid, 2014). Results from an aerial survey conducted in the Serengeti-Mara ecosystem in 2014, identified about 192 elephant carcasses, of which 117 were found in the northern part while 75 in the southern part of the ecosystem with 84% and 27% of it inside and outside the protected area respectively (WWF, 2014).

The Tanzanian wildlife policy of 1998 introduced a Community Based Natural Resource Management (CBNRM) approach that was revised in 2007 to promote the management of wildlife resources outside the protected areas by establishing Wildlife Management Areas (WMAs) (URT, 1998). WMAs aid in mitigation and prevention of conflicts between human and wildlife as the approach enables the local communities to have authority and a participation platform for managing wildlife on their land (Wilfred, 2010). The Tanzania's Wildlife Conservation Act of 2009, describes the management of human-wildlife conflict by suggesting a number of approaches including problem animals control and consolation for loss of life, crops or injury caused by wild animals (URT, 2009). According to Perea (2009) elephants consume approximately 150 kg of food daily, causing crop raiding by elephants a major problem to local communities around protected areas (Bitala, 2004). Absence of an effective buffer zone between protected areas and human settlements or farmlands in Ikorongo-Grumeti Game Reserves is a major source of the conflict (Kideghesho, 2006;

Nelson, 2012). In 2003/04 season about 323ha (732 tons) of crops were damaged by elephants while about four people were reported to be killed by elephants (Walpole *et al*., 2004). Mwakatobe *et al.,* (2014) found that in the 9 surveyed villages around Serengeti National Park, and Ikorongo and Grumeti Game Reserves, the mean estimated cost of crops damaged per household by raiding elephants in 2014, were about USD 31.49 (Closest villages), USD 14.06 (Medium villages) and USD 12.1 (Far away villages). All these cause dissatisfactions and in the long run have inculcated hatred of animals and in many cases with revenging behaviour (Chang'a *et al.,* 2016). With the ongoing wildlife conservation efforts, recent spatial observation trends have shown that the elephant population in Ikorongo-Grumeti Game Reserves has been increasing from 355 to 1320 elephants from 2003 to 2014, fueling the existing human-elephant conflicts (Nelson, 2012; Goodman, 2014).

Despite the rise in human-elephant conflict, there is little information that is known on the current efforts towards introducing new approaches for addressing the problem. This is because most of traditional techniques such as chili essence, guarding farms, scaring elephants using noise and pungent materials, planting alternative crops and buffer crops around fields, and benefit sharing (Gross *et al.*, 2016; Pittiglio *et al.*, 2014) have shown short-term impact still leaving a wide security gap to be filled. On that note, a research was done to identify and recommend novel approaches and techniques for managing HEC in western Serengeti area, Tanzania. This paper presents novel approaches that can be applied to help mitigate HEC in western Serengeti and in areas with comparable situations.

MATERIALS AND METHODS

Study area

This study was carried out in Ikorongo-Grumeti Game Reserves and the surrounding villages which lie between latitudes 1º30' and 2º45' S and longitudes 33º00' and 35º30' E. The area covered by Ikorongo and Grumeti Game Reserves is 563km^2 and 416 km^2 respectively (Fig. 2) (Kideghesho and Mtoni, 2008). The area experiences two rainy seasons occurring in March-May (long rains) and November-January (short rains). Annual rainfall ranges between 500 mm and 1200 mm while annual temperature range of between 21°C and 27°C (Goodman, 2014). The area is home to more than 20 tribes, most of them engaged in agriculture and livestock keeping (Kideghesho, 2006).

Study design

A cross-sectional research design was employed in collecting primary data from the study area. Six villages were purposively selected based on the nearest distance from the protected area boundary and number of human-elephant conflict incidents reported. The villages selected were Nyamatoke, Hunyari, Iharara, Makundusi, Nyichoka and Bonchugu. Simple random sampling method was used to select 50 households from the village registry book of each sampled village. Generally, a total representative sample of 300 households for the study from the target population of 3004 households was obtained of which 55.7% were female and 44.3% were male.

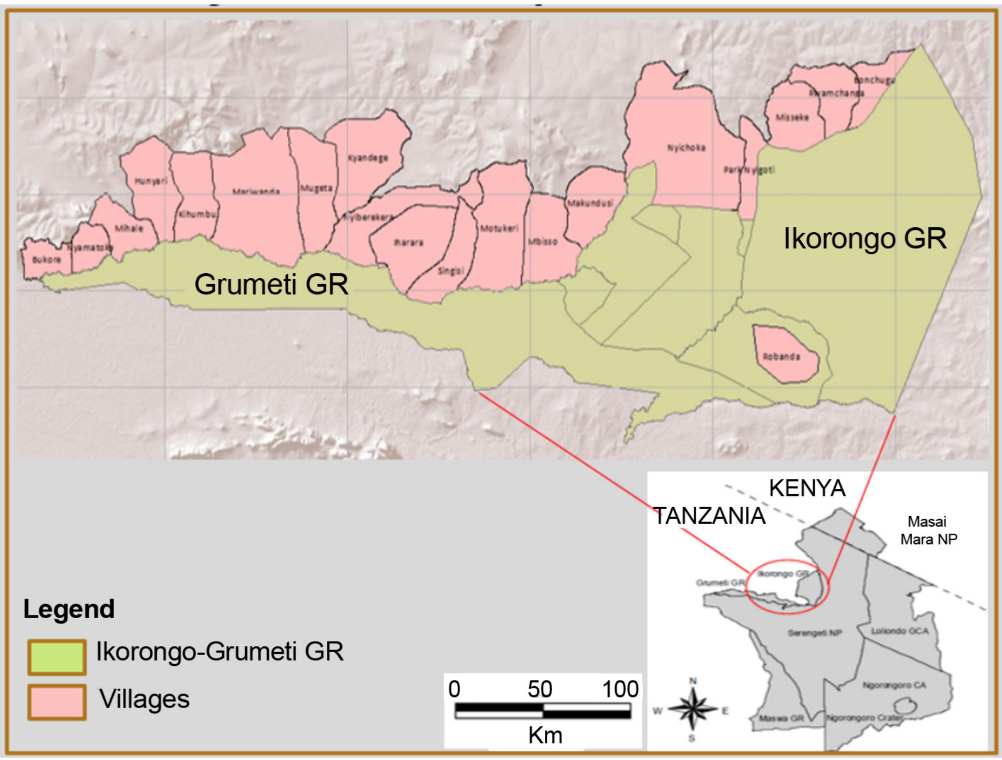

Figure 2. Map of Serengeti Ecosystem, with the study area cycled in red

Data collection

Data were collected using mixed methods namely direct observation, house hold surveys and key informants interview (KIIs). Through direct observation the researcher visited the study area observing different anthropogenic activities taking place within surrounding communities. Moreover, 300 questionnaires with close and open ended questions were administered to respondents from the sampled households. Moreover, twelve (12) key informants who were District Game Officers (DGOs), SGF staffs, Village Executive Officers (VEOs) and elderly villagers both men and women were purposively chosen based on their political position, experience and authority. Secondary data were obtained from various sources including books, journals, research papers and relevant reports from Singita Grumeti Fund, Bunda and Serengeti District Game Offices and Village Government Offices (VGOs). The data provided up to eight (8) years period information on the status and trend of human-elephant conflict incidences.

Data Analysis

Qualitative data obtained from the survey were analysed using content analysis. Content analysis involved summarizing through breaking down the recorded dialogue into the smallest meaningful units of information and opinions of respondents over the study topic (Kajembe, 1994). Quantitative data were verified, compiled, summarized, coded and analysed using R version 3.3.3, and Statistical Package for Social Science (SPSS, version 12.3) computer software. Descriptive statistics including frequencies, percentages and cross-tabulation were generated. All statistical analysis was conducted at the alpha=0.05 significance level.

RESULTS AND DISCUSSION

Demographic characteristics

The demographic characteristics of the surveyed households from all six villages showed that 55.7% of the respondents were female and 44.3% were male. Age distribution of respondents varied from 18 to ≥66 years with majority being in the active age group of 18-35 years. Moreover, most of the surveyed households depended on crop farming (43.7%) and mixed farming (38.7%) as their prime source of income whereas the remaining 17.6% were businessmen.

Conflict analysis and conflict management strategy

Conflict resolutions through meetings and provision of consolation money were mostly applied (Table 1), but still felt unsatisfied by the affected communities. The approach is definitely unsustainable and short lived, therefore it is imperative that more relatively long term and sustainable approaches be sought to address the issues at stake. In this regard, a package of mitigation approaches and techniques for HEC that are cost effective, easy to apply and friendly to the environment, but able to resolve the current wide spread problem are of paramount. Therefore, the sections below present discussions on relevant findings that will facilitate the transformation of the currents HEC using the suggested approaches.

Potential Unconventional Approaches and Techniques for HEC Mitigation

As result of the less effective HEC mitigation measures being applied in the western Serengeti for ages and the subsequent short term impact, there has been an increased demand for more effective measures with long-term impact to prevent and mitigate the HEC. Due to an advance in technology, the use of un-conventional mitigation measures together with traditional techniques has been showing fairly positive results. According to Dhanaraj and Sangiah (2017) and Sheela *et al*. (2016), application of advanced techniques in the management of HEC across the global has shown positive impacts with long-term results.

Following the study survey that was conducted in the sampled villages from Bunda and Serengeti Districts, respondents from the surveyed households suggested new six measures (Fig. 2). The survey was based on the opinion regarding the performance of different techniques for combatting the problem.

Table 1. Conflict analysis and strategy design table

CONFLICTING PARTIES	ISSUES AT STAKE	IMPORTANCE OF ISSUES*	INTERESTS	OPTIONS FOR MITIGATING THE CONFLICT	WILLINGNESS TO SETTLE THE CONFLICT	NEXT STEPS
Local communities (farmers & Pastoralists)	-Crop damage -Human life threats (killings & injuries) -Infrastructure damage -Domestic animals threats (killings & injuries)	**VH** **L** **M** **VL**	– Protect crops from damage – Human life Security from being killed or injured by elephants – Better access to decision making – Maintenance of Customary rights of occupancy – Access to pasturage and water sources	– Contribute to support the new mitigation measures (53.4%), provide manpower (35.3%) and ready to be relocated (22%)	– Distrust of government and PAs management (bad experiences) – Would only continue a talk if process perceived as fair	– Conduct conflict resolution meeting at village level to address the issues and strategies among villagers
Elephants (Represented by PAs management)	- Blocking migratory routes -Loss of habitat (food, water & shelter) -Elephants killings & injuries	**VH** **H** **L**	– Prevent degradation of habitats (food, water & shelter) – Prevent elephant killings and injuries – Maintain environment in which humans live in harmony with nature	– Provision of conservation education – Use of more effective mitigation measures	– Prefer to use Community Outreach Programs (COP) rather than force – Would use force when necessary	– Platforms to conduct conflict resolution meetings and forums to develop strategies to address the issues

Source: Adapted from Conflict Detection and Resolution (CDR)

***Key: VH**=Very high priority**, H**=High priority**, M**=Medium priority**, L**=Low priority**, VL**=Very low priority

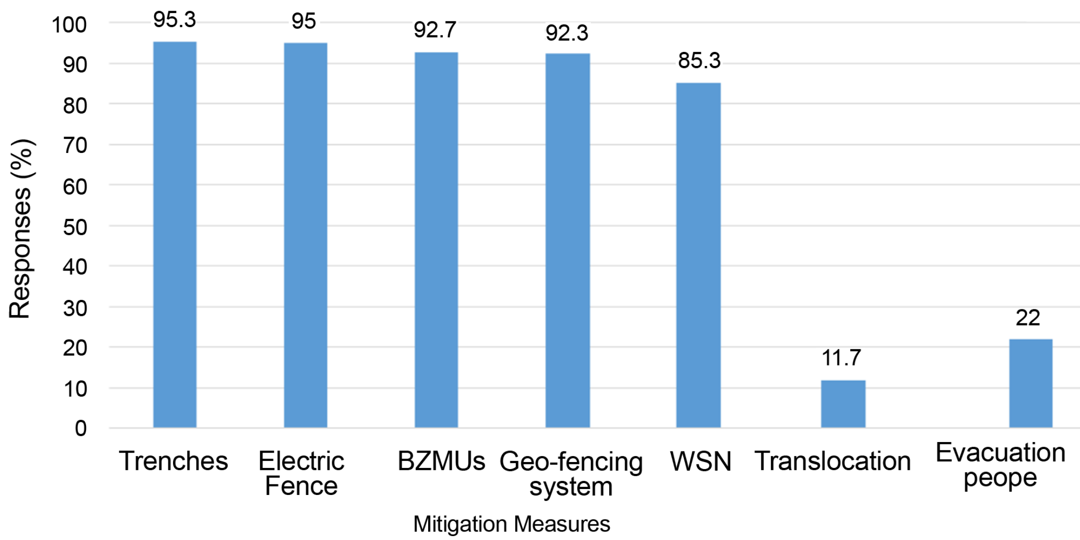

Figure 2. Unconventional HEC mitigation measures

Potential Unconventional Approaches and Techniques for HEC Mitigation

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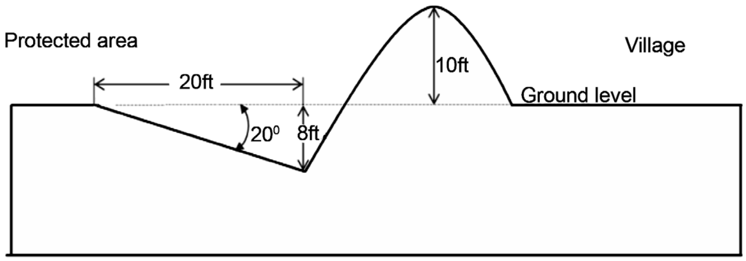

Figure 3. Schematic diagram of the proposed trench construction

Construction of trench

A trench, about 20ft wide and 8ft deep is excavated at the reserves edge (Fig. 3). It is a deterrent to non-jumping animals like elephants. The soil excavated from the trench is heaped on top of one side of the bank, making the trench to appear deeper, limiting the problem animals to cross from PAs into villages. The technique has been applied around majority of national parks in India, Sri Lanka and Uganda (Babaasa, *et al.*, 2013; Mackenzie and Ainebyona, 2012). The results from the study found that 95.3% of respondents in the surveyed villages indicated that trench construction could be applied as an unconventional mitigation measure to the HEC. They further considered the technique to be effective as a physical barrier that will prevent elephants moving out of the protected areas boundary into village land.

Electric fencing

Majority of the respondents in the surveyed villages (95%) indicated that erection of electric fence along the boundary between IGGRs and villages will have a positive impact over the conflict as it will restrict elephants' movement from PAs into farmlands located along the reserves boundary (Plate 1). Electric fences have been quite effective in preventing problem animals, particularly habitual raiding elephants in majority of countries facing the HEC (Babaasa *et al.*, 2013). The technique acts as the physical barrier preventing the elephants from invading farms in the village land bordering the protected areas.

Plate 1. An electric fence limiting elephant crossing from PAs into villages
(Credit: RDB, Rwanda**)**

Buffer zone management units (BZMUs)

Majority of the respondents (92.7%) from the surveyed villages suggested delineation of a clear buffer zone between the IGGRs, Ikona WMA boundary and its adjacent villages. They further suggested establishment of BZMUs dedicated to the protection and management of the buffer zone. Buffer Zone Management Units (BZMUs) comprise of specialized personnel dedicated to respond quickly upon elephant's invasion or when about to cross from PAs into village land. Moreover, establishment of the BZMUs should be in line with establishment of permanent ranger posts along the buffer zone across the villages.

Geo–fencing system

Majority of the respondents (92.3%) indicated that the technique will have an effective and long-term impact to the mitigation of HEC in the conflict zones of IGGRs. Geo-fencing system was also among the unconventional mitigation measures identified during the study survey. The system involves a virtual fence line within a computer geographical information system (GIS) and programmed in geographical positioning system (GPS) positions into the tracking collar of crop raiding elephants, which creates a Geo-fence around the particular animal (Gupta and Harit, 2016; Mathur *et al.*, 2017). If the elephant strays outside of its known range or tries to enter a local village to raid crops, Global System for Mobile Communication (GSM) elephant collars with installed Subscriber Identity Module (SIM) cards send a SMS text message to the control center or BZMUs manager alerting them of the immediate problem, and the location of the elephant, enabling rangers, VGS and reserve staff to locate and drive back the elephant into the reserve boundaries.

Wireless sensing network (WSN)

Results from the surveyed households indicated that 85.6% of respondents considered wireless sensing network (WSN) another category of approaches and techniques for HEC mitigation measure. WSN based systems are widely used for various purposes such as warning system against different hazard scenarios (e.g. fire) and research on detection of movement and distribution patterns of wild animals (Dhanaraj and Sangiah, 2017). Such WSN based system can also be effective to generate an early warning against the presence of elephant near the village land and thus can prevent potential human-elephant conflict scenarios. The proposed technique uses the Very High Frequency (VHF) transmitters embedded in the collar fitted on elephant body that are connected to track the location of the animal while approaching the restricted area. The VHF transmitters attached to the problem elephant emit a pulsed radio signals, which when the animal is within the range, the signals are detected by the receivers erected on poles or towers. The signals taped by receivers are sent to a gateway node having a signal processing unit to filter specific signal of particular frequency. Signals from gateway node will be received by a central processing unit (CPU) (Ramkumar *et al*., 2014; Sheela *et al*., 2016). This processing unit will look for a pattern match of incoming signal with a reference signal to detect and confirm the presence of elephant within range. Once the CPU confirms the presence of an elephant it will generate warnings and send the information to the nearby HWC office with specific location codes through GPS. Functioning of the proposed WSN system has been shown in the below Fig. 4.

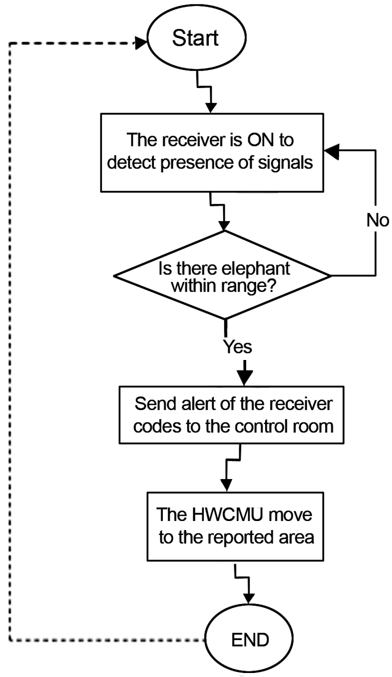

Figure 4. Schematic diagram of the proposed integrated WSN for Elephant Detection

Translocation of problem elephants

The least number of respondents in the surveyed villages (about 12%) indicated that translocation could help in the reduction of problem elephants hence incursions and raiding pressure on crop fields. Translocation is the removal of a problem animal by tranquilizing and transporting it to a new location where they are released, using specially designed vehicles and specialists' expertise. With this approach, Translocation of animals has been undertaken in Kenya (Litoroh *et al.*, 2001) and South Africa (Garai and Carr, 2001), among other countries. Translocation may appeal more to conservation organizations because it has a number of advantages, including saving elephants from being killed, stabilizing the elephant population within the habitat carrying capacity, and taking obvious action that satisfies local communities who are normally confronted with conflicts. Before translocations can be undertaken, preliminary studies of the social structure of the elephants need to be conducted so as to avoid disruptions that can affect family and other elephants.

Evacuation of people

In the study villages, about 22% of the respondents considered the evacuation of people as an alternative measure that will have effective and long-term solution to the conflicts compared to translocation of the problem elephant by nearly 10%. This proposal was anchored on the observation that distance from PA to settlements demonstrates a significant relationship with intensity of conflict. The observation is not surprising because elephants are known to move distances from day to day, in search of suitable habitat where they can obtain basic needs such as food and water (Harris, *et al.,* 2008). This can be evidenced as the amount of crop damaged varied in the study villages with the change in the average distance of the surveyed households and farms in each village. As the encroachment of PAs by settlements together with cultivated land seemed fuelling the damage of crops and increase in threats to both human and domestic animals, relocation of people living near protected areas is inevitable. People should be evacuated in the areas which are reported to be the conflict zones and those which are very close (<0.5km) to the IGGRs and Ikona WMA boundary.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The local communities used traditional mitigation measures together with the efforts from HWCMUs and PAs authorities to control elephant attacks. Despite these efforts, several barriers needed to be addressed to make the mitigation measures more effective as elephants have showed very high adaptability to most of the applied deterrents. These included the use of local tools as the primary means to chase the elephants, low income and education level and large distance between ranger posts and villages.

Several unconventional mitigation measures were therefore identified and recommended as mitigation measures with expected long-term impact to the HEC between local communities and elephants of the IGGRs and Ikona WMA. The measures were construction of trench, electric fencing, buffer zone management units (BZMUs), geo-fencing system, Wireless Sensing Network (WSN), evacuation of people near protected area boundary and translocation of problem elephants. The implementation of these methods requires a long timeframe, financial resources as well as, importantly, political will. It is essential that human-elephant conflicts mitigation becomes an integral part of the national wildlife conservation policy. Strengthening trans-border cooperation is needed to manage elephant populations across IGGRs, Serengeti National Park, Ikona WMA and other nearby PAs. Development of a rigorous decision-making framework will require the participation of various stakeholders such as government ministries responsible for management of natural resources, social welfare and land-use planners, PAs management authorities, natural and social scientists and economists and local people from communities adjacent to PAs.

There is a need for a clear policy and strategic planning. The current approach to dealing with conflict is largely ad hoc, and predisposed to failure because of inappropriate application of methods, limited involvement of local people, lack of effective monitoring of conflicts and conflict mitigation measures, and inadequate understanding of elephant ecology in deploying mitigation strategies. In the absence of new and improved wildlife conservation approaches, there will be more conflicts between people and wildlife particularly elephants due to their large home range and free ranging. No single solution is effective and different approaches need to be integrated to address the problem proactively.

RECOMMENDATIONS

With reference to the study findings the paper recommends the following:

Planting palatable crops (maize, millet, among others) close to the reserves boundary by has led to the hike in crop raiding incidences within the landscape. It is recommended that farmers be encouraged to engage in cultivation of non-target crops like onions, chili, peanuts and sesame which are mainly commercial crops. Also, in collaboration with PAs management and other stakeholders, communities in the study area should be assisted to adopt new and sustainable techniques to deter elephants from raiding their crops as suggested in this study. On the other hand, bee keeping projects can be another option where community members can harvest and sell honey and beeswax, whereas beehive fences can enhance crop production and eventually improved rural livelihoods. Local people should be encouraged to improve village-based guarding efforts to detect and deter elephants prior to their entry into crop fields. This should be in line with the use of more sophisticated tools like long-range flashlight torches, among others as suggested in this study.

Recommendations for PAs management

For effective management of HEC it is important for local people to have understanding on scientifically-proven drivers of the HEC. Hence it is recommended that the IGGRs and Ikona WMA put more emphasis on conservation education among local people at various levels and seek to address the socio-economic and livelihood aspects of the communities. Community involvement in conservation activities in the study area should be a priority in the GMP of the IGRRs and Ikona WMA. Such an approach will increase sense of belonging in community. IGGRs Ikona WMA management in collaboration with the government of URT should consider implementing the HEC mitigation measures suggested in this study, for effective and long-term mitigation of HEC in western Serengeti. The IGGRs management should also consider using GPS satellite telemetry to monitor and record the spatial and temporal distribution and movement patterns of elephants and their activities within and outside the PAs boundary. This should focus on identifying individuals and groups and monitoring their movement patterns in relation to crop raiding in order to obtain long-term information for effective operation of the new conflict mitigation measures identified in this study.

Policy Recommendations

The wildlife conservation sector should consider to incorporate and put into action the potential and alternative long-term mitigation measures such as erecting electric deterrents, which are non-lethal to reduce the conflict between people and wildlife as suggested in Section 3.3.12 of the Tanzania wildlife policy of 1998. It is recommended that government should set up a trust fund to compensate a greater proportion of the elephant-caused damage. Shared policy changes would enhance people's perception towards and an ownership of those elephants being conserved. It is further recommended for the government to create a clear and well defined buffer zone separating the IGGRs and the surrounding communities.

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Dynamics of human - elephant conflicts in villages surrounding Ruaha National Park, Tanzania

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ABSTRACT

Human- Elephant Conflict (HEC) is among the challenges facing conservation of elephants and their respective habitat across the world. However, these conflicts vary in space and time due to numerous factors including variation in human population, land use typologies and the population of elephants. The study presents findings on the dynamic of HECs in Tanzania with case study of Tungamalenga and Mapogoro villages surrounding Ruaha National Park from 2010 to 2020. The study used four methods namely; Household survey, where a total of 70 respondents were interviewed, two Focus Group Discussions, 6 Key Informant Interviews, and 4 site visits. Over the past ten years, there is increased in HEC which has been accelerated by human population growth and number of elephants increased. The growth of elephant's population from 2015 triggered increased HEC in both villages. From this study it can be concluded that causes, impacts and mitigation measures of HECs is the function of time and space. Conservation authorities and all stakeholders dealing with HEC should consider time and space when designing strategies to mitigate HEC.

Keywords: Conservation, Dynamics, Household, Human-Elephant conflicts, Mitigation

INTRODUCTION

Human-Wildlife Conflict (HWCs) is one of the oldest phenomenon in human history (Asimopoulos 2016; Anand and Radhakrishna 2017; Attia et al. 2018) However, to date the conflict has become severe (Anand & Radhakrishna 2017), thus increasing threats to wildlife, people and their properties. HWC occur whenever needs of human and wildlife overlap (Asimopoulos 2016) or when they share same landscapes and resources (Bakker, 2019). Understanding causes, impacts and mitigation measures of various HWCs is one of the key steps in developing strategies for sustainable conservation and management of wildlife (Water & Matteson, 2018). Among all taxa of wild animals, large mammals are known to be the most important cause of HWCs due to damages they cause to communities (Enukwa, 2017). Elephant is among the key species affected by HWCs due to large demand of their home range in search of space, forage and water (Mateleb et al. 2011), their social organization, ranging behaviour, and ecological needs influencing their interactions with human. Across the globe, conflicts between human and elephants are the results of competition for limited space and resources (Mateleb, Rahman, and Sultan 2011). In Tanzania Human-Elephant Conflict (HEC) is a key challenge in wildlife conservation and livelihood of communities, however, the conflict varies with space and time (African Wildlife Conservation Society, 2010). Villages surrounding Ruaha National Park (RUNAPA) are reported as one of HEC's hotspot in Tanzania (Mduma, *et al*., 2010), this can be due to large elephants' population which grows to 3% per annum in Ruaha-Rungwa ecosystem (Mduma et al. 2010). The study conducted in 23 villages surrounding RUNAPA reported an increase in elephant damage in communities' properties and threatening their lives from 325 incidences in 2015 to 577 in 2016 (Stein, 2017). To date, little is known about variation of HEC at relative smaller/fine spatial scale in terms of areas, time, causes and mitigation. It is from this understanding that, this study was conducted to assess the dynamics of HEC in Tanzania using a case study of two villages of Tungamalenga and Mapogoro situated adjacent to RUNAPA. Specifically, the study identified main causes of HEC between years 2010 to 2020, impacts of HEC on different livelihood activities, and examine mitigation measures used to minimize elephants' damages.

MATERIALS AND METHODS

Study area

The study was conducted in Southern Tanzania focusing on two Villages adjacent to Ruaha National Park (RUNAPA). RUNAPA forms a part of Ruaha-Rungwa ecosystem which is known for its numerous elephants herds, highest population density of elephants and harbour the second largest elephants population in Tanzania after Selous (Mduma et al. 2010). The Park is characterized by semi- arid climate with only one rain season (normally from November to May of the following year) and dry season which starts from June to October. Average annual rainfall varies from 500mm to 800mm, with temperature ranging from 27^0 C (day) to 15^0 C (at night) in dry season and 28^0 C (day) to 17^0 C (night) in wet season. The study villages are part of Pawaga-Idodi Wildlife Management Area. These villages are found in Idodi division in Iringa Rural District of the Iringa Region, Tanzania. This division is situated immediately South of Ruaha National Park. Village's locations include (7^0 48′ 0′′ S, 35^0 4′ 0′′ E for Mapogoro and 7^0 47′ 0′′ S, 35^0 1′ 0′′ E) for Tungamaleng (Fig. 1).

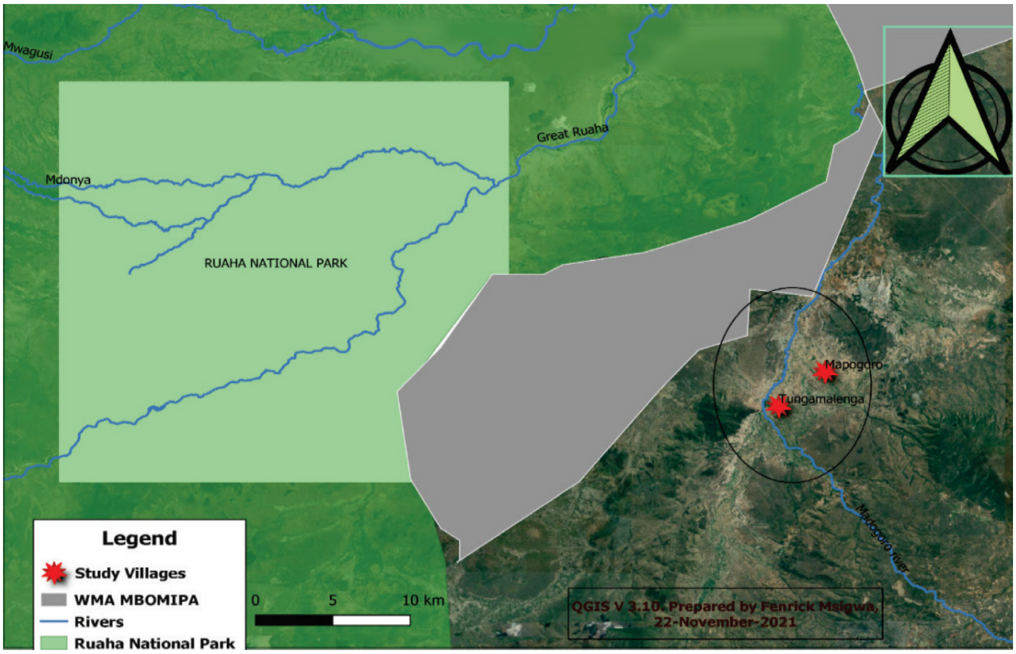

Figure 1. Map of Ruaha National Park, PI WMA and the location of study villages

Data collection methods

Household surveys

A total of 70 respondents were interviewed. Respondents were selected according to the number of sub villages within the villages where village chairman assisted in understanding number of people to be involved. The larger the number of people living within the sub villages the more the number of respondents. Within the village, household were selected due to its fully involvement on agriculture and an experience on crops raiding by elephants. This method enabled to get information on causes, impacts and mitigation measures of HEC from the community facing HEC, and comments regarding the dynamics of HEC.

Key Informant Interviews (KII'S)

Key Informant Interviews (KII'S) were used to gather information from park ecologist, village leaders, experts and stakeholders. In total 7 people were KII where two are village leaders, two agricultural officers, two researchers and Ruaha park ecologist who who confirmed the increase in number of elephants in this area. Key informants revealed the dynamics of HECs to support information obtained from household survey. Village leaders provided information on the social- economic impacts of HEC and mitigation measures used in respective villages and data on population trend.

Focus Group Discussions (FGDs)

FGD's were conducted with two groups farmers totalling 17 participants (8 in Mapogoro and 9 in Tungamalenga) due to the reason that the intensity of crop raiding in this area is higher than any other sources of conflicts. The FGD was meant to collect information on HEC issues that are underway in their village and way forward.

Site visits

Site visits involved researcher's eye observation in study areas to see some observable phenomenon on existence of HECs. Elephant signs such as dung, crops raiding, properties destruction and foot prints were assessed. In addition, selected farms were visited to observe and experience some local methods used to mitigate HEC.

Data analyses

Data from questionnaire was coded and analysed using SPSS version 16.0 to derive descriptive statistics and frequency. How did you analyse data from FGDs, KIIs and field observations?

RESULTS

Demographic characteristics

A total of 70 respondents who were members of the household were interviewed in the household survey, mostly being males (64.3%). Respondents were grouped into four age groups which included young, youth, adults and elders respectively (for respondents below 18 years, their closet adult were consulted for informed consent) 18-49 years, 50-60 years and above 60). The results showed that, the majority of respondents (58.6%) had an age between 18-49 years. Household size varied; however, the average was six individuals. Majority of respondents (87.1%), mentioned crop cultivation as their major economic activity. Education level among respondents was as follow; 51.4% had primary education level, 27.1% had secondary education level; 4.3% had tertiary education, while 17.1% had non-formal education. These demographic data was helpfully in understanding dynamics and trends of crop raiding.

Table 1. Causes of HECs mentioned by respondent in Household survey in each village

Causes of HECs	Village	
	Tungamalenga	Mapogoro
Scarcity of water and availability of palatable crops in the village	51.43%	34.29%
Elephants have lost fear to people	22.86%	20.00%
Human activities conducted along former wildlife corridors	14.29%	20.00%
Proximity to the park	8.57%	17.14%

Causes of HECs

The causes of HEC in the survey village were presented in Table 1 although 2.84 of respondents in Tungamalenga and 8.57% in Mapogoro didn't know the causes of HEC (Table 1).

Human population growth

For the past ten years, Tungamalenga village had higher number of human populations triggered by immigration compared to Mapogoro. The trend shows the growth was about (11.43%) in Tungamalenga and 2.79% in Mapogolo. This growth is likely to accelerate human elephant conflicts due to increase agricultural activities and settlements which led to blockage of elephant corridors.

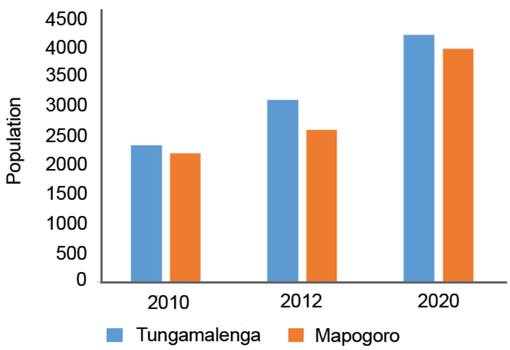

Figure 2. The trend of human population in study village

Availability of Palatable crops in villages

With exception to sunflower, other primary cultivated crops in both villages were very palatable, hence crop raiding by elephants (Table 2). Respondents informed that crop raiding was also influenced by scarcity of water and palatable forage during dry season, thus palatable crops in the village was best option for elephants in dry season.

Table 2. Percentage of crops grown in the study villages

Primary crop	Percentage of respondents
Maize	50.3
Rice	18
Fruits	13
Sunflower	9.7
Beans	9

Increase of Elephant population

From 2014 to 2020 Elephants' population in Ruaha National Park has been increased (Fig 3). The Respondents argued that, with recent increase in elephant population, large herds of elephants roamed in their village with no fear.

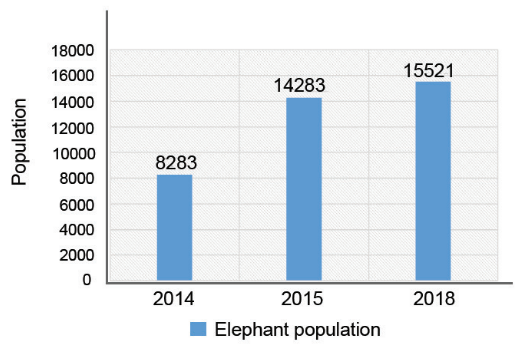

Figure 3. Trend of Elephant population in Rua-ha-Rungwa ecosystem (Source: RUNAPA, 2020)

Impact of HEC

Crops raiding was reported 57% of respondents. It was emphasized that crop raiding peaks in dry and harvesting season which starts from June to October. Apart from physical damages caused by elephants in crops and properties, other impacts mentioned include insecurity and fear causing lack of freedom to walk at night and limited accesses to some key resources as well as sleepless nights to guarding farms (Table 3). The impacts of HEC are dynamic in nature and extent where some impacts were mentioned to have existed before 2010 but recently have not been witnessed.

Table 3. Percentage impact of HEC in Tungamalenga and Mapogoro villages

Impact	**Village**	
	Tungamalenga	Mapogoro
Crops damage	54.80	60.00
Destruction of infrastructure	19.00	14.29
Sleepless night guarding farms	10.20	9.73
Limited accesses of some potential needs like firewood, water and grasses	7.43	8.57
Limited freedom of mobility especially at night	5.71	7.41
Injury and Cattle killing during grazing	2.86	0.00

HECs mitigation measures

Most respondents (57%) reported to have used a combination of methods in mitigating HEC as no single method was effective when used alone. Preference of mitigation measures used varied between two villages, with guarding, use of fire and chill being highly used in Tungamalenga while disturbance noises and bee hives fences, being preferred in Mapogoro village (Table 4).

Table 4. Percentage of mitigation measures used against crops raiding in Tungamalenga and Mapogoro village

Mitigation measures	Village	
	Tungamalenga (%)	Mapogoro (%)
Combination of methods	34.29	25.71
Guarding	14.29	11.43
Disturbance noises	5.71	11.43
Use of chill	11.43	2.86
Use of Visual materials	5.71	11.43
Planting unpalatable plants	5.71	8.57
Use of fire	17.14	5.71
Bee hive fences	2.86	11.43
None	2.86	11.43

Discussions

The increase of elephant population was revealed to be a trigger for increased HEC in Tungamalenga and Mapogoro villages. Respondents reported that before 2015 the frequency and intensity of crop raiding was low, this was likely to be caused by intensive decline of elephant's population due to poaching from 2009 to 2014 (AWF, 2015). In the period of intense poaching elephants had more fear and stress of being poached, thus most of the population were confined inside the park. Experts addressed that from 2016 the population of elephants in Ruaha- Rungwa ecosystem has increased, due to effective ant-poaching strategies implemented by the government of Tanzania (Jilala & Kashaigili, 2014; Ng'wanakiala, 2019) and conservation stakeholders. Increase of HECs due to rise in elephant's population was exacerbated concurrently by human population growth from immigration and natural birth. Population growth was high in Tungamalenga village than in Mapogoro village, probably because Tungamalenga is developed in terms of petty business especially selling local goods and other services to tourists. Respondents realized that their villages suffered a lot from HECs because they were close to Ruaha NP as well as the MBOMIPA Wildlife Management Area. Thus, it was easy for elephants to smell their matured crops during harvesting season. In Focus Group Discussions, respondents argued that being close to protected areas is the reason of having many incidences with HEC and hence they would like to be taught better mitigation measures. Similar to what was reported by Blair & Meredith, (2017), different people and age class have different views and interest about HEC. In this study, the causes of HECs mentioned by respondents were similar in all villages.

Crop raiding was the main form of HEC reported in the study villages, and has been reported in several other areas of the country (Mmbaga *et al*., 2017; Weinnmann, 2019). Other studies also revealed that crops raiding can be accelerated by scarcity of resources in protected areas which forced elephant to forage outside the park (Kalyanasundaram & Balasundaram, 2014). Availability of palatable crops with sugar contents in villages such as maize, sugarcane, paddy and fruits such as mangoes, watermelon, pawpaw trigger elephants to raid crops, which mostly occurs when are ripening (Blair & Meredith, 2017). The result showed impacts of HECs are changing with time and space as it was reported that respondents experienced death of human by elephants and retaliatory killing of elephants for more than ten years ago. Currently, they observed no any fatal incidence probably due to education and campaign programs which have been given to community by village leaders and other conservation projects such as Wildlife Connection as quoted by village leader from Mapogoro; "we are teaching people that elephants are gentle but dangerous, thus people tend to be careful and we advise them to avoid walking at night especially in areas where elephants tend to be seen frequently".

Despite crop raiding being a major impact of HEC for so long, respondents mentioned that there were changes in increased in size of farms raided, frequency of elephant's visitation in farms and villages as well as change in crops preference. This was caused by an increase of elephant population experienced in Ruaha- Rungwa ecosystem since 2016 (Ng'wanakiala, 2019). Villages in the study area have mentioned to have employed different measures to mitigate HEC in their village, however no single method has been successful hence need to use a combination of methods. This indicates that effective HECs mitigation measures are difficult to understand and problematic to implement at different temporal and spatial scales (Hoare, 2012).

In terms of blockage of wildlife corridors and its role in increasing HEC, respondents (14.29% in Tungamalenga and 20.00% in maporogolo) respondents especially with age of 50 who lived in village for more than 30 years pointed out that some parts of village development activities are conducted in elephant corridors. Many years ago, those areas were open without farms or human settlements but due to human population growth the areas are now used for farming and human settlements, but elephants can still remember these areas and visit them frequently.

Hence the result from the study implies that HEC incidences vary across temporal and spatial scale, similar to the mitigation measures. Therefor in managing human elephant co-existence it is important to understand these variations and account for them to ensure sustainability. The observed variations in HEC incidences were highly influenced by increase of elephant's population as well as human population growth accompanied with land use transformation and changes in farming practices. Mitigation measures used in the villages were based on indigenous knowledge. Besides, and their effectiveness varied even at fine spatial scale and when used in combination rather than when singly used. Due to scarcity of time and resources this study didn't cover all aspects of dynamics of HECs in the study areas. More studies are recommended to conduct a longitudinal study to establish the influence of space and time in the nature and extent of HECs, based on daily, monthly and seasonal variation in HECs over several years. Findings from such studies will provide a frame-work to deal with HECs.

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Engaging village scouts enhances wildlife conservation under informal wildlife setting in Mwanga District, Tanzania

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Abstract

Wildlife conservation requires holistic involvement of government, local community and non-governmental players. Using data collected by community scouts in three villages in Toloha Ward, Mwanga District, Tanzania, we illustrate the role of community scouts in wildlife monitoring and conservation in an informal wildlife area and how simple methods can be used to deter human-elephant conflict. Although it is key habitat linkage between Mkomazi National Park and Tsavo National Park, Toloha lacks formal protection and faces habitat degradation, unplanned settlement, small-scale farming, poaching and escalating human-wildlife conflicts. Eighteen scouts were selected jointly with the local community and trained by District Council of Mwanga and African Wildlife Foundation (AWF) on security, conflict mitigation/management and data collection using Cybertracker application installed in Samsung J1mini prime phones. Scouts collected data on human wildlife conflicts, wildlife presence and any illegal human activity within the corridor on routine patrols. Data collected from May 2019 to August 2021 were imported and analyzed on Spatial Monitoring and Reporting Tool (SMART) and Social Package for Social Sciences (SPSS). Presence and patrols conducted by village scouts improved conservation outcomes remarkably, trophy poaching declined by 70.6% despite increased visitation by wildlife to the villages (23 mammal species recorded by August 2021), poaching by snares declined by 81.8%, habitat destruction (firewood collection) reduced by 82.6% and crop raids interception rates stood at 42.7% in 2021. Our results demonstrate that strategically placed and coordinated scout units, in community areas can effectively secure species and habitats forming a lasting basis to improve livelihoods of local people living with wildlife. Challenges to sustaining these successes emanate from inadequate resources for program upkeep including livelihood improvement. Our work calls for scaling up this approach.

Keywords: Community scouts, conservation, human-wildlife conflicts, management

Introduction

Wildlife conservation contributes significantly to Tanzania's Gross Domestic Product and overall human wellbeing (Kyara *et al.*, 2021). However, threats to wildlife including poaching, human wildlife conflict, habitat loss and degradation are increasing, causing Africa's wildlife populations to decline (Kideghesho *et al.*, 2013; Ogutu *et al.*, 2016). Africa's wildlife populations will decline unless clear and innovative strategies are devised to stabilize or increase populations *in situ*. Wildlife population declines are exacerbated by increasing human population and inadequate alternative sources of income often associated with encroachment to wildlife protected areas (PAs), corridors, dispersal areas and other important areas.

Wildlife species occur and require space beyond formal protected areas. Protected areas are key but inadequate to effectively protect and manage healthy wildlife populations (Kideghesho *et al.*, 2013; Riggio *et al.*, 2019). The best way to conserve the species is by holistic involvement of relevant stakeholders including government, local communities, private sector and nongovernmental players. Engaging local communities in biodiversity conservation is vital to successful wildlife conservation in Africa including Tanzania (Infield and Tolisano, 2019, Kiffner *et al*. 2020, Lee 2018).

Village Game Scouts (VGS) are popularly engaged in Wildlife Management Areas (WMAs) in Tanzania (AWF, 2013) but also can be engaged as security reservists in villages. These VGS have shown an impressive record by assisting in wildlife conservation in their respective WMAs. For example, they act as a bridge between the local community and the wildlife authorities, live within the villages and can respond to an incident within the shortest time possible, gather intelligence information and thus enhance combatting illegal wildlife trade and human-wildlife conflict mitigation.

Communities in rural Africa often live with wildlife and suffer opportunity costs through crop raids, attacks, livestock depredation, property damage and death (Matseketsa *et al*., 2019; Manoa *et al*., 2020). These vices have brought in friction between local community and wildlife. The situation worsens due to poor public relations between local communities and wildlife authorities coupled by lack of direct benefits accrued from wildlife (Thondlana and Cunbill, 2017; Mutanga *et al*., 2017). Apart from poor public relations, the wildlife authority rangers take long to respond to the reported cases of human-wildlife conflict. Moreover, no consolation or compensation is paid in majority of cases. Compensation, if it happens, involves a long tedious process characterized by bureaucracies. In most occasions, where the local community members are victimized by rangers for wildlife loss through poaching or retaliation, the pain spread like fire in the villages. In return, the local community become non-committal in any wildlife engagements that foster wildlife conservation and management.

In such conditions, the wildlife authorities find it difficult to engage the community in development projects, access information on poaching and Human Wildlife Conflict (HWC), experience hostility because of negative attitudes and perceptions from the local community. On the other hand, the local community are easily swayed by wildlife offenders through sharing of information on wildlife movements and ranger operations, participate in poaching and illegal wildlife trade, host poachers or even retaliate through poisoning, spearing or inflicting injuries to wildlife which in most cases is indiscriminate (Harrison *et al*., 2015).

The scenario has contributed to population declines, habitat destruction and blockage of wildlife corridors/paths. However, several innovations have been applied to make sure this is reversed which include establishing community relations and engagement departments within the wildlife authorities, introducing corporate social responsibility projects in hotspot areas, establishing WMAs/conservancies, revision of policies and laws to ease processes in consolation and compensation, wildlife kitties e.g. bursaries, school programs, establishing community programs like lion guardians, wildlife monitors, training of communities to mitigate conflicts and formation of VGS units in community areas (Roe *et al*., 2020).

In March 2017, Mwanga District Council (MDC) and African Wildlife Foundation (AWF) in collaboration with local community established a VGS unit in Toloha Ward to assist the community in mitigating HWC and by extension work with the wildlife authorities to combat illegal wildlife trade. The VGS were enrolled on a volunteer basis with payment of stipends whenever resources could allow. This is one of the exceptional approaches of engaging VGS compared to the normal engagement through a WMA.

This paper illustrates the role of community scouts in protecting and monitor wildlife in an informal wildlife conservation area of Toloha Ward in Mwanga district, Tanzania. This study aimed at showcasing the importance of VGS in enhancing security for wildlife, deterrence of poaching and habitat destruction, and supporting the local community in mitigating human wildlife conflict. This was achieved by seeking answers for questions that included does presence of VGS strengthen security of wildlife which would increase wildlife visitation measured using encounter rates and group sizes? Do presence of scouts increase deterrence to bushmeat and trophy poaching? Do they contribute to habitat protection by reduction of illegal firewood collection and charcoal production? And lastly, what are their roles in mitigating human wildlife conflicts within the villages? Are they able to increase the interception rates? This project is ensuring that inhabitants of Toloha Ward continue to have wildlife as a resource on their lands thus creating opportunities to improve their livelihoods and overall wellbeing through nature conservation.

MATERIAL AND METHODS

Study area

Toloha Ward is located in Mwanga district on northern part of Tanzania, between 3^{o}.40’-3^{o}54’S and 37^{o}.43’-37^{o}58’E (Fig. 1). The Ward comprises of three villages namely Gongoni, Simu Kizungo and Karamba Ndea. The area forms part of the eastern lowland side of the north Pare mountains with an altitude range of 500-700 meters above sea level. The rainfall rarely goes beyond 700 mm per annum and it is split into two seasons where the short rains occur in November-December and long rains in May-July (Bagambilana and Rugumamu, 2019). Temperatures range between 14 ^{o} C and 30^{o} C with the coldest months in June-July and hottest in January (Bagambilana and Rugumamu, 2019). Toloha falls in between a wildlife dispersal area and path connecting Mkomazi National Park in Tanzania and Tsavo West National Park in Kenya (Penrod *et al*., 2020).

Toloha is rich in flora and fauna. The floral structure is supported by the fertile soils which is made up of bushland dominated by acacia (Richard *et al*., 2013). Nevertheless, the open areas are either bare or covered by shrub grasslands. The bare areas are regularly subjected to soil erosion and thus deep gullies are easily formed in the lowland areas. The areas close to Lake Jipe are dominated by water logging species which include reeds, papyrus and grasses. These areas are therefore suitable for a variety of fauna which include elephants, buffaloes, eland, giraffe, lesser kudu, impalas, grant gazelles, hippo and a range of birds and insects.

The Pare community reside in the villages of Gongoni and Simu Kizungo while the Masai community are dominant in the Karamba Ndea village. The Pare are mainly crop and livestock keepers with subsistence in hunting and honey gathering while the Masai are purely livestock keepers.

Until the year 2017, Toloha had no VGS. During a farmers training and engagement meeting held in collaboration between

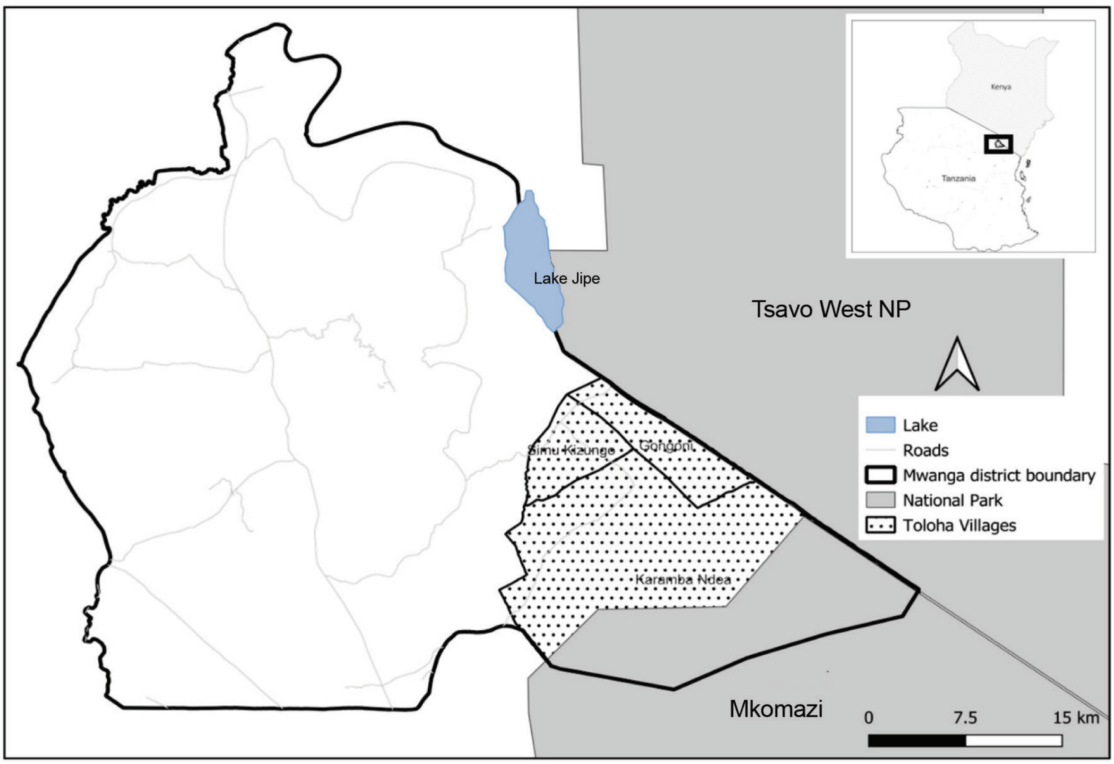

Figure 1. Location of Toloha Ward and its villages in Mwanga district. The villages are adjacent to Mkomazi and Tsavo West National parks (please note boundaries are indicative).

MDC and AWF in Toloha Ward, the farmers requested for establishment of a VGS unit to assist them in mitigating HWC. With the guidance of the District Game Officer of MDC, a unit was established in Toloha with a 6-member unit from each village considering age, gender and willingness to volunteer. The members were endorsed in the village councils and assemblies.

A 14-day induction course was conducted for the selected VGS and later on equipped with uniforms. The induction covered areas such as conducting a parade, paramilitary discipline, first aid, how to conduct patrols, report writing, chain of command and wildlife laws. Subsequent refresher trainings were organized to bring the team to speed based on the areas of weakness. Further, the teams were enrolled for a month's course at Passiansi training college for further training. Several trainings with farmers on HWC mitigation were also conducted which entailed use of simple tools like torches, pressure horns and fire crackers. In addition, a communication strategy was developed to allow for good coordination between the farmers, VGS and the wildlife authorities (Tanzania National Parks (TANAPA), Tanzania Wildlife Management Authority (TAWA), and Kenya Wildlife Service (KWS).

In 2019, the VGS were trained on data collection and recording using cybertracker and reporting using Spatial Monitoring and Reporting Tool (SMART). More trainings were organized to polish on areas where the VGS had challenges and regular checking on the progress was conducted to make sure all was well. The data collection was based on the model developed for the scouts which captured data on patrols conducted, date and time, Global Positioning System (GPS), wildlife sightings, illegal activities (trophy and bushmeat poaching, charcoal production, firewood collection, trespass, livestock incursion, poachers' camps and logging) and HWC. The data collected by the scouts was used to analyze the patrol effort, wildlife sightings, illegal activities and HWC for this study.

Data analysis

The VGS patrol effort was calculated using the SMART software where number of patrols, patrol days and kilometers covered over the years were grouped per month. Wildlife species sighted by VGS were summarized using a pivot table in Microsoft excel©. We calculated the encounter rates for selected wildlife species (elephant, giraffe, impala, kongoni and zebra) representing large to small bodied herbivores. The data for the carnivores were not sufficient for analysis. The encounter rate was calculated by dividing the number of sightings per kilometers patrolled per species per year (Gowda and Kamara, 2009).

The recorded illegal activities were grouped into four categories which included bushmeat, snares, firewood and charcoal production. The data was analyzed to check for any deterrence based on the catch per unit effort index (quantities/number of incidents against the patrol effort calculated based on the kilometers patrolled before the incident was encountered) by the VGS (Dobson *et al*., 2018). A correlation analysis was later undertaken for the index against time (years) for each of the illegal activities. The higher the r^2 value, the more reliable the test while the negative correlation indicate presence of deterrence which means the illegal activity decreased as patrol effort increased (Dobson *et al.*, 2018).

For human wildlife conflicts (HWC), descriptive statistic values were used. The interception rates were calculated using the following equation Interception rate = (number of intercepted incidents/total incidents) *100

Further comparison was undertaken for different years. Independent sample t-test was used to analyze data grouped to two years and one-way ANOVA for the three years using p-value of 0.05.

RESULTS

Patrol effort

A total of 31,396.2 kilometers was covered by Toloha VGS between May 2019 and August 2021 by completing 1,199 patrols in 1,287 patrol days. The VGS covered more kilometers in 2019 compared to those of 2020 and 2021 (F = 3.566, df =2, p < 0.05). The same scenario was reflected by the number of days spent in patrol (F = 8.974, df =2, p < 0.05) and number of patrols conducted (F = 11.325, df = 2, p < 0.05).

Wildlife sightings

Toloha Ward forms an important wildlife dispersal area which is indicated by the number of species sighted (23 mammals and ostrich). Nevertheless, 20 species were recorded in 2019 which later got 3 additions in 2020 to reach 23 species but in 2021, the species encountered dropped to 19. The additions in 2020 were cheetah, wildebeest and aardvark.

On the sampled large herbivores, the encounter rates of elephants declined over the years (Table 1) while for giraffe, the encounter rate increased to 0.07 in 2020 but later on declined to 0.04 in 2021. The same scenario was exhibited by impala and zebra. Kongoni encounter rate reduced in 2020 from 0.05 in 2019 to 0.04. The rate remained the same in 2021.

Table 1. Wildlife encounter rate for the selected wildlife species that visited Toloha over the years

Species	**Encounter rates (sightings / kilometer)**		
	2019	**2020**	**2021**
Elephant	0.06	0.05	0.04
Giraffe	0.06	0.07	0.04
Impala	0.04	0.06	0.05
Kongoni	0.05	0.04	0.04
Zebra	0.07	0.08	0.04

Illegal activities

Between May 2019 and August 2021, no trophy poaching was recorded in Toloha Ward. On the other hand, there was no significant difference in the number of bushmeat cases recorded in 2019 and 2020 (t_9 = 0.031, p > 0.05) with no cases recorded in 2021. Nevertheless, there was deterrence based on the quantity of meat (kilograms) and incidents recorded per kilometers patrolled by the VGS (table 2).

In 2021, there were no snares encountered by VGS during their patrols. The number of snares was significantly lifted by VGS between 2019 and 2020 (t_{11} = 3.067, p < 0.05) with the year 2020 (M = 5.0, SD = 2.8, n = 2) attaining a higher score than 2019 (M = 1.9, SD = 1.0, n = 11). In addition, the VGS managed to reduce the number of snares lifted which matches reduction in number of incidents of snares per kilometer (table 2). There was a drastic decline on snares incidents by 81.8% between 2019 and 2020.

On firewood collection, we found that there was no significant difference in the quantity of firewood collected over the three years (F = 0.10, df = 2, p > 0.05). However, the number of firewood bundles encountered and number of incidents per kilometer showed a significant decline over the years (table 2). 82.6% decline on illegal firewood collection was experienced between 2019 and 2021.

Charcoal production on the other hand was recorded in 2019 and 2020 with no significant variations (t_{15} =1.02, p>0.05) despite 2020 (M=5.8, SE = 3.8, n = 5) recording a higher score than 2019 (M=3.1, SE=0.8, n=12). Though there was a reduction in number of bags encountered and number of incidents of charcoal, the deterrence was low (table 2).

Human wildlife conflicts

Toloha recorded high cases of crop raids (85.3%, n=232) compared to human attacks (5.9%, n= 16) and livestock depredation (8.8%, n= 23). Despite that, the crop raid incidents have been on a significant decline since May 2019 (r > 0.99, N=3). For the total number of crop raids, 99% of the cases were caused by elephants while 1% were attributed to buffalo. The number of elephants causing the conflict over the years did not vary (F= 0.231, df=2, p > 0.05).

Different methods have been employed by the VGS in mitigating the crop raids which included use of torches (57.8%), hooting (18.5%), thunder flashes (12.5%) and making noise (11.2%). This has contributed to 42.7% interception rates and thus minimize damages to crops. Nevertheless, in 2.2% occasions, the species got scared and ran but came back again to attack while in 2.6% the species instead of running away, attacked the scouts. The remaining 52.6%, the mitigation was employed after crop raiding had already occurred or was a reporting case where attack occurred prior to scout visitation.

During the study period, there were 24 cases of livestock depredation reported with

Tabled 2. The deterrence based on the catch per unit effort put by VGS in the different illegal activities using the slope and the r^2 values of the correlation analysis.

Illegal activity	Numbers counted per kilometer		Number of incidents per kilometer	
	r^2	*Slope*	r^2	*Slope*
Bushmeat	0.907	-0.177	0.868	-0.022
Snares	0.601	-0.257	0.998	-0.135
Firewood	0.588	-0.123	0.833	-0.062
Charcoal	0.545	-0.235	0.465	-0.034

elephants as the main culprit (81.3%). One case each was recorded for leopard, hyaena and buffalo.

DISCUSSION

Toloha scouts conducted their patrols in three groups (Karamba Ndea, Simu Kizungo and Gongoni). In 2019, we used data for 9 months while for 2020 it was 12 months and the first 8 months for 2021. Despite the time variations, patrol data for 2019 varied from those of 2020 and 2021. The drop in the number of kilometers covered, number of patrols conducted and the days spent in patrols may be affected by various factors which included availability of resources to conduct patrols, the type of patrol conducted (foot, motorbike, vehicle) and coordination (Critchlow *et al*., 2019). Since the teams rely on well-wishers to support them through provision of fuel, food and probably equipment, which in most cases is not consistent, such variations may affect the patrol effort. In 2019, the scouts were trained on the cybertracker data collection and supported to conduct patrols. This boosted their morale and thus more kilometers covered using motorbikes plus availability of vehicle from TAWA. In 2020, the Covid 19 pandemic broke and affected financial support to the team as well as restrictions that came with by the ministry of health guidelines. The same trend cut across the wildlife and tourism sectors in Tanzania (Kideghesho *et al*., 2021).

This study has confirmed that Toloha Ward is one of the areas increasingly utilized by wildlife. This could be demonstrated by the number of HWC reported earlier especially for elephants before May 2019. The increasing number of different mammal species encountered by the VGS was incredible having in mind only 10 species were encountered by scouts in 2017 immediately after their establishment. And with availability of a VGS unit that builds the bridges of coexistence between the local community and wildlife, Toloha can attract more wildlife species. We saw more additional species in 2020 which can depict the kind of trend that can be expected if the VGS does their work right (Kablan *et al*., 2017). Aardvark is one of the shy species and it is an additional conservation advantage to sight them in the villages of Toloha. Before 2017, most of the Toloha villagers were not sure if ostriches would ever visit their villages after disappearance in the early 90s (per comm from Rashid Rajabu). Such visitation by wildlife to the villages can only be related to the VGS effort.

Toloha villages play a big role in supporting wildlife movements and dispersal from Mkomazi and to Tsavo West National Parks and vice versa. Lake Jipe is nearby and plays a big role in providing water for wildlife in the nine dry months of the year. The encounter rates of the selected wildlife showed that the species utilization of the villages vary. The variation may depict the importance of the villages as a dispersal or corridor area for wildlife.

Elephant encounters have been on decline over the years despite no variation in their distribution over the years. The decline in elephant encounter rates can be attributed to the regrouping (average group size of 9, 14.6 and 14 was recorded for the years 2019, 2020 and 2021 respectively) of the elephants into large numbers probably because of the favorable conditions prevailing in the villages (Duffy *et al*., 2011). The average number per sighting for 2019 was about 9 individuals while for 2020 and 2021 was 15 and 14 respectively. This is a good indication of low sightings but large numbers within the villages.

Presence of VGS in the villages might have led to increase in encounter rates of giraffe, zebra and impala between 2019 and 2020 despite reduced patrol effort. Giraffe, zebra and impalas in most cases fall victims of bushmeat and thus tend to avoid areas with poaching pressure. This scenario therefore implies that the presence of scouts increased the deterrence of bushmeat poaching which led to increased security for the species (Critchlow *et al*., 2019; Bi *et al*., 2019). The decline on encounters the following year might be attributed to the local dispersals between the village and TWNP as they distributed close to the park. Cokes hartebeests on the other hand showed a decline of encounter rate between 2019 and 2020, then, stabilized. Cokes hartebeest distribution over the years were at the boundary of TWNP and thus easy to retreat into the park.

Poaching of wildlife for their trophies has been recorded in Toloha. Between 2016 and 2018 (as per the MDC records), a total of 31 elephants poaching incidents (some led to death or intention aborted or intercepted) have been recorded in Toloha ward. However, the number of incidents in 2016 were high compared to those of 2018 by 70.6%. The VGS has been a strong deterrent to poachers mainly due to their presence and sharing of information to wildlife authorities. A Tanzania Wildlife Management Authority (TAWA) camp was also established at Toloha in 2019 that works very closely with the VGS and thus reinforced the security. However, this has not impacted much on the bushmeat activities. Though presence of VGS has led to reduction of the amount of meat poached, the number of cases encountered is reducing but in a slow pace. Bushmeat incidences might be challenging for the scouts to handle especially in differentiating the wild meat from livestock and most of the bushmeat is for subsistence.

Most of the bushmeat poachers have changed their way of hunting wildlife. We can see this by reduction of number of snares used over the years. However, we noticed that the snare coverage in 2019 was distributed in a larger area with probably low numbers but in 2020, the snares were set in specific areas though in large numbers. This behavior by bushmeat poachers might be an adaption to avoid VGS, reduce time spent in setting and monitoring the snares or it is about the wildlife numbers and distribution (Rija and Kideghesho, 2020).

Collection of firewood in the three villages was restricted through use of permits issued by the MDC. Initially, the firewood vendors could use fake or expired permits to gain entry to collect firewood in Toloha especially in Karamba Ndea which is one of the identified villages that can supply firewood to nearby towns e.g. Mwanga. One of the roles of the scouts was to help in inspection of the permits as they conduct their patrols. Since the vendors knew they had no option but to have permits and also collect the permitted size of firewood, the cases of illegal collections reduced drastically.

Charcoal production within the villages of Toloha exist but VGS have not be in a position to deter it. This has been attributed to lack of clear laws governing the charcoal production. In most cases, the local community advocate that the charcoal produced was due to their land preparation for farming. And in most cases, they get a back-up from a few village officials. This has affected the VGS operations.

HWC is ever rising in local communities where humans and wildlife interact. For Toloha, since most of the residents are mixed farmers (crop and livestock farming), the different types of conflicts are expected especially where elephant visitation to the villages are evident (Su *et al*., 2020). High cases of crop raids were recorded in Toloha where majority of the villagers are crop farmers (Gongoni and Simu Kizungo villages). One of the main roles of establishment of a VGS unit in Toloha was to assist the local farmers in fighting the menace (AWF, 2013). The trends of the conflicts have proven the strategy worked with reduction in conflicts despite no change in elephant's population causing the conflicts all year round and increased visitation.

However, the reduction of the cases might be attributed to other factors and not VGS alone. Farmers were trained in several occasion on the tools used when scaring wildlife from the farms, coordination strategy between farmers, VGS and TAWA and general behavior of wildlife. All these strategies combined contributed to 42.7% interception rates. This led to pumper harvest in the villages which was not possible in previous years. For livestock depredation and human attacks, we believe that little can be done by VGS to reduce them without appropriate mitigation strategies like predator proof enclosures (bomas) and improved livestock husbandry practices.

CONCLUSION

Based on the results of this study, we conclude that VGS play an important role in protection, conservation and management of wildlife with clear and consistent support from all the stakeholders in the sector. This can be possible if proper structures are put in place.

We recommend that Toloha VGS model can be scaled-up in other areas with no WMA status with close monitoring and support from the authorities. Wildlife authorities like TANAPA, TAWA and district/village councils can make sure they support the VGS in executing their roles through provision of financial, technical and policy support. And lastly, livestock depredation and human attacks can be mitigated by other strategies rather than depending on VGS. Exploring on other interventions like improved bomas, improved livestock husbandry practices, wildlife monitoring and coordination, change of human behavior and education and awareness is necessary.

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PERCEPTIONS AND ATTITUDES OF COMMUNITIES TOWARDS INDIAN HOUSE CROW (*Corvus splendens*): A CASE STUDY OF TANGA AND DODOMA REGIONS, TANZANIA

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ABSTRACT

Indian house crow has become a problem to communities and the environment since its invasion to Tanzania in the 1880s. The species affects the communities socially, economically and ecologically leading to different perceptions and attitudes from people towards the bird species. The study explores the perceptions and attitudes of local communities in Tanga and Dodoma regions towards the bird species. The respondents were from randomly selected households who were 18 or above years. A qualitative and quantitative method that involved a questionnaire, Focused Group Discussion (FGD) and direct observation was adopted including 604 respondents from Tanga and Dodoma regions. Data were analyzed using SPSS 25 version for window. The perceptions and attitudes of local people towards the bird species were largely negative suggesting a negative social impact of the birds to communities. The noted negative impact of the birds included stealing food, money, necklaces and underwear. Also, the birds contaminate the environment, attacking livestock and destroying crops. The duration of interactions with the birds shaped the perceptions and attitudes of people. It is recommended that sustainable and ecologically suitable C. splendens population control measures such as the application of biological procedures be sought. Also, education to communities and public awareness about the socio-ecological impact of the bird species should be conducted in affected areas.

Keywords: Perceptions, attitudes, communities, Indian house crow

INTRODUCTION

The Indian house crow *(Corvus splendens)* is a native bird species to the Indian subcontinent. Its geographical range extends from southern Iran, across Pakistan, India, Bangladesh, Sri Lanka, Bhutan, bordering southern Nepal, and extending eastward through Myanmar and southern China (Csurhes, 2010). Currently, the genus crow (*Corvus*) is found in all continents apart from their original geographical ranges, from North America, Europe, Australia and Africa through shipping by the colonialists in the late 1880s to remove or reduce wastes in the environment in the islands of Zanzibar. Tanga Region experienced the existence of the bird many years back compared to Dodoma Region, which has recently experienced the existence of the bird (Ryall, 2016).

Ecologically, successful dispersion of the birds has been favoured by their adaptation characteristics including lacking natural predators. Based on their feeding behaviour, the birds are typically omnivorous capable of feeding on large number of stuff including rubbish, kitchen leftovers, debris from various sources, and sewage. They also eat reptiles such as lizards, fish, amphibians (frogs), insects (crabs, grasshoppers, beetles), fruits, the seeds of different cereal, eggs, chicks and small mammals (Suliman *et al*., 2010). Some authors has regarded the birds as skilled feeders eating everything as long as it is edible whether dead or alive (Ramakrishna *et al*., 2010)

Increasing population numbers of the birds may pose threat to ecological systems due to their feeding and reproductive behaviours, especially, to East African ecosystems that are already stressed by introduced species and anthropogenic activities adjacent to the ecosystems (Fraser *et al*., 2015). These effects may go directly to people who surround these ecosystems leading to negative attitudes and perceptions towards the birds.

This study aimed to explore the perceptions and attitudes of local communities living in Tanga and Dodoma regions towards the *C. splendens*. Specifically, it determined the duration the local communities in Tanga and Dodoma regions had interacted with the bird species. It also investigated the effect of the birds on the communities in Tanga and Dodoma regions. Last but not least, the study explored the attitude of communities towards the birds in the two regions.

METHODS

Description of the study area

This study was conducted in Tanga and Dodoma regions from February to May 2021 Tanga and Dodoma were selected purposely because *C. splendens* had already spread and colonized these regions. In particular, Tanga was selected because the birds were originally introduced in Zanzibar Island, which is close to Tanga. Hence, when they crossed the ocean to mainland the chances were to colonize the coastal areas including Tanga Region. People in Tanga are assumed to have interacted with these birds since their establishment in the 1970s (Ryall, 2016). In this town, the assumption is that

people are more informed about the impact of these birds and that would lead to negative perception and attitude towards the birds. According to Shimba and Jonah, (2017), the birds were first spotted in Dodoma Region in 2017, hence obtaining data from the area would compare well with long-term introduction and interactions between the two species (*Homo sapiens and C. splendens*) in the two regions.

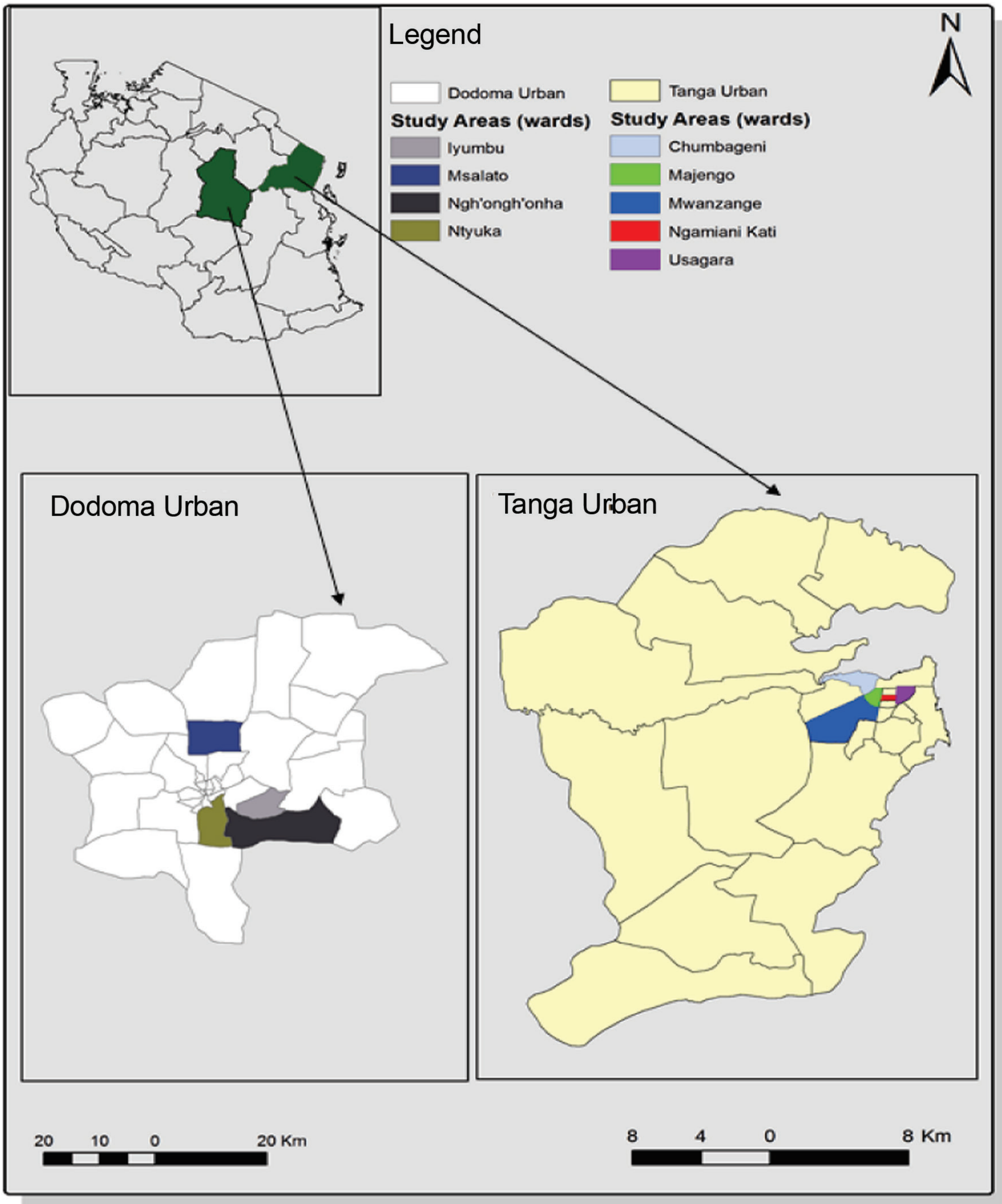

Figure 1. The Study area including sampling wards

Geographical Locations of the Study Areas

Tanga Region is situated in the north-eastern part of Tanzania between Latitude 4^0 and 6^0 south of the Equator and Longitude 37^0- $39^0$10’ East of Greenwich (Figure 1). It is characterized with high humidity with binomial rainfall, which falls between April and May (long rain) and between October and November (short rain). The mean annual rainfall is 1100 mm-1400 mm, which favours *Acacia mangium and Enterolobiu mcyclocarpum* typically used for firewood and charcoal. More vegetations include *Brachystegia speciformis, Microphylla spp*, *Combretum angolensis, Dombeya rotundifolia*, *Dalbegia melanoxylon, Sterculia spp*, and *Julbernadia spp*. Others are *Bridelia micantha, Commiphora africana, Commiphora eminii, Flacourtia indica, Juniperu sprocera, Milicia excelsa, Ocotea usambarensis, Rauvolfia caffra* (Hines & Eckman, 1993).

Dodoma is the capital city of the United Republic of Tanzania (URT) (Figure 1). The region lies between Latitudes 6.00^0 and 6.30^0 South and Longitude 35.30^0 and 36.02^0 East (*Statistical Abstract*, 2011). The region is characterized by a long dry season with a single wet season lasting from December to March with an average rainfall of 570 mm (Dejene, Yanda & Johnsen, 1997). The area is dominated by deciduous xerophytic grasses, herbs and shrubs the common shrub in the area is mainly *Dichrostachys cinerea.* Common trees include different species of Acacia such as *Acacia tortilis, A. seyal*, *A. nilotica*, *A. mellifera,* and other species like *Adansonia digitata*, *Comiphora species, Brachystegia speciformis* and *Euphorbia candelabra* (Dejene *et al*., 1997).

Research design

The study employed a cross-sectional study design where the outcome and exposures from participants were measured by an investigator (Setia, 2016). This design allows the collection of data from a population, which takes place at a single point in time that also requires a short time. It is cheap and requires few resources to conduct the study (Hemed, 2015).

Population and sampling

Target population

The targeted population of this study were adults aged 18 years and above living in the two selected regions.

Sampling design

This study based on both probability and non-probability sampling. The two regions (Tanga and Dodoma) were purposively selected while the wards streets and households were selected using simple random sampling.

Sampling units

The sampling units were selected randomly from the sampling frames constructed. One of the sampling frames was constructed using the ward list obtained from the districts under the study in a give region. The list consisted of the arranged name of wards based on alphabetical order. The random number generated from a calculator (CASIO *fx*-100 MS) was used to assign each ward a number, the generation of random numbers suggested which ward to pick (i.e. when the first random number read 0009, we took the last two digits, for this case it would be 09 which is then 9^{th} ward along the list). In case the number read 0077 while the list had only 40 names of wards, the number picked was the average of the last two digits (i.e. 7+7/2 = 7). The procedure was repeated until the number of wards required was attained. A similar procedure was maintained for streets within the selected wards.

Sample size

The sample size (n) was 5% of the total number of households (N) in each of the study wards as modified from Nyahongo et al., (2009). A household is defined as family members living and eating from a common pot or a person who lives alone and provides for his or her essentials alone. It can be made of more than one house or part of it or it can be whole.

Sample size distribution

The sample size was distributed proportionally in each ward depending on the population of a given ward (At least 5% of the total households in a given ward were picked) (Table 1).

Table 1: Distribution of the Respondents Interviewed per Ward in the two Regions

Region	Wards	Total no. of h/hold	Total no. of respondents
Tanga	Chumbageni	1867	117
	Usagara	1427	85
	Mwanzange	899	54
	Majengo	475	76
	Ngamianikati	589	72
Dodoma	Iyumbu	711	57
	Ntyuka	892	65
	Msalato	820	41
	Ng’hong’hona	740	37
Total		**12081**	**604**

Source: WEO of respective ward in 2021

Data collection techniques

Different methods and techniques were adopted to triangulate information. This was accompanied by different data collection tools such as questionnaires, Focused Group Discussion (FGD) and physical observations.

Quantitative data collection

A questionnaire survey was used in this study to collect quantitative data which included both open and closed questions and collected information on the effects caused by the birds. The researcher and the research assistants administered questionnaires to the respondents directly. Each respondent was required to answer all questions. In case the respondent failed to answer all questions from the questionnaires, his/her incomplete questionnaire form was discarded, hence not included in the subsequent analysis. During the interview, no member of the family was allowed to assist in answering questions. However, the development of coping behaviour and the way the local people were reacting to *C. splendens* was identified during Participatory Rapid Appraisal (PRA) which involved participant's direct observation, group discussions, and secondary data that were obtained from other sources.

Qualitative data collection

This focused on the attitudes and perceptions of the community on the *C. splendens.* FGD was used to obtain the data whereby a list of questions in the form of checklist was used. In each ward, a small group of about 6-8 people were identified based on the experience and expertise of the individuals. The questions were posed to the group for discussion. The researcher recorded the issues raised by the participants. The group considered gender. Youth and female participants were encouraged to participate in the discussion in a group including men. The male dominance was discouraged by posing a question directly to either a female participant or a young person in the group. FGD was done twice at different places within the chosen wards.

Participants' observation

When in the study area, the researcher observed and recorded the birds' activities within the area. This kind of information was recorded as incidental because there was no generalized probability of their occurrence. The information was then used in general discussion. Moreover, participants from the communities under the study were encouraged to report any interesting information through their insights into the field of the birds' interesting impact to the communities.

Data analysis

Quantitative data were entered into a personal computer. All statistics were performed using SPSS (25th version for window). The information from the structured questionnaire was coded and analysed using quantitative such as Mann-Whitney Tests (for comparing the information gathered from the two regions). For qualitative data such as interviews, observation and FGD we used qualitative data analysis techniques, specifically contents analysis, after summarizing and coding the information gathered. Non-parametric tests were used because most of the variables were ordinals, hence not normally distributed. For descriptive data, the findings were summarized as a percentage or as Mean ± Standard Error of Mean (SEM). All results were summarized in Tables and Figures. For all comparisons, $p < 0.05$ were considered significant. However, when $p = 0.0001$ or less than the figure provided, which implies highly significant, the representation was set as $p < 0.001$.

RESULTS

Social demographic characteristics of the respondents in Tanga and Dodoma regions

Demographic characteristics of the respondents in the two regions included age categories, sex, marital status, level of education, household size and employment status are summarized in Table 2. When the household size were split in two regions and compared, the results revealed significant differences between the two areas (Mann-Whitney test; U = 27074.500, $p < 0.001$).

Table 2: Socio-demographic Characteristics of the Respondents Interviewed in Tanga and Dodoma Regions (n = 604).

Variables	Classification	Tanga (n=404) %	Dodoma (n=200) %
Age	18-30	24.6	56
	31-40	26.9	16
	41-50	23.1	11.5
	51-60	12.7	8.5
	61-70	8.5	6.5
	71-80	3.7	1.5
	>80	0.5	0.0
Sex	Male	34.2	39
	Female	65.8	61
Marital status	Married	67.1	76
	Unmarried	32.9	24
Education	Informal	6.9	8
	Primary	62.4	60
	Secondary	26.2	26
	Tertiary	4.5	6
Household Size	1-6	70.2	89
	7- 13	26.7	11
	14-20	2.9	0
	>20	0.2	0
Employment Status	Employed	7.2	8.5
	Unemployed	92.8	91.5

Perception of local communities towards the *C. splendens* in the two regions

Perception as adapted and applied in the current study is the way in which *C. splendens* presence to the environment is regarded, understood, or interpreted by communities in the two regions using only their senses. Positive perception means the respondents had no or little negative experience with the birds and for negative perception means the opposite.

Overall, respondents who had negative perceptions towards the birds were 61.1% (n =604). Those with positive perceptions were only 6.6% (n = 604). The remaining 32.2% were neutral. Considering gender in perceptions, overall**,** 61.9% (n = 388) of all female respondents in Tanga and Dodoma regions had negative perceptions. However, good number of female respondents (31.4%, n = 388) were neutral while only 6.7% were positive. Male respondents from the two regions who had negative perceptions were 59.7% (n = 216), those who were neutral were 33.8% while those with positive perceptions were only 6.5%. The overall analysis revealed that the perception of female and male respondents towards the birds in the two regions were similar (Mann-Whitney test; U = 40996.500; P > 0.05) (Table 3). When male and female respondents opinion's concerning the benefit of birds to both environment and community, were compared, only 14.2% (n = 388) of female respondents claimed the bird to be beneficial while 29.6% (n = 216) males claimed the same. The two groups' opinions on the issue differed significantly (p < 0.001, Table 3).

Table 3. Gender influence on perceptions of the local people in Tanga and Dodoma regions on C. splendens

Variables	Classification	Tanga and Dodoma (Female)(n=388) %	Tanga and Dodoma (Male) (n=216) %	P-values
Perception	Dislike	61.9	59.7	0.595
	Indifferent	31.4	33.8	0.545
	Like	6.7	6.5	0925
Opinion	Beneficial	14.2	29.6	< 0.001
	Indifferent	20.9	15.7	0.119
	Not beneficial	64.9	54.6	0.013

When the perceptions of male and female respondents in each region were compared separately, the results revealed similar perceptions (Tanga: Mann-Whitney Test; U = 17766, P > 0.05; Dodoma: Mann- Whitney Test, U = 4423 P > 0.05).

Attitude of local people towards the *C. splendens* in the two regions

Attitude, as adapted to this study is the way in which a respondent from both Tanga and Dodoma regions views and evaluates *C. splendens* either positively or negatively based on their own experience. Overall, 61.1% (n = 604), of all respondents in both regions, disliked the bird while 32.3%, neither liked nor disliked the bird, i.e., they were indifferent. In contrast, only 6.6% of all respondents claimed to like the birds.

When the study areas were separated into two regions, the respondents from Tanga Region who had negative attitude towards birds were 77.0% (n = 404) compared to

28.5% (n = 200) with the same attitude from Dodoma Region. Those respondents from Tanga Region who had neutral attitude towards the birds were 18.1% against 61.5% from Dodoma Region. Furthermore, the respondents from Tanga Region who had positive attitude towards the birds were only 6.6% compared to 10.0% from Dodoma Region. In general, the attitude of the respondents from Tanga Region was more negative towards the birds than those from Dodoma respondents (Mann-Whitney Test; U = 22399.000, P < 0.001). Surprisingly, those who did not have any opinion regarding the bird in Tanga Region were only 18.1% while in Dodoma Region they were 61.0%. Analysis suggests that the respondents in Tanga had experienced the presence of the birds many years back compared to the respondents from Dodoma Region (Mann- Whitney Test; U = 1771.000, P < 0.001) (Table 3).

Table 4. Attitude of Local People towards the C. Splendens in Tanga and Dodoma regions

Variables	Classification	Tanga (n=404) %	Dodoma (n=200) %	P-values
Attitude	Dislike	77	28.5	< 0.001
	Indifferent	18.1	61.5	
	Like	5	10	
Benefits for positive attitude	No benefit	90.30	94	0.134
	Ecological benefits	0.20	1	0.174
	Attractive	0.02	1	0.174
	Clean environment	0.04	1	0.368
	Tourism	0.20	1	0.053
	Eat ticks on cows' skin	0	1.5	0.436
	Money	0.2	0	0.842
	Eat harmful organisms (snakes, bats and insects)	1	0	0.655
Effects for negative attitude	Attack crops	0.6	1.3	0.373
	Thief (i.e., steal food, money, clothes etc.)	49.2	16.6	<0.001
	Unhygienic	33.5	3.1	<0.001
	Attack people	5.8	0	<0.001
	Attack livestock	6.4	8.2	0.414
	Annoying	2.3	1.3	0.405
	Cause electric shock	1.3	0	0.105
	No effect	11.9	69.1	<0.001

Duration of interactions between *Corvus splendens* and communities in the two regions

Respondents from Tanga Region unlike those from Dodoma have interacted with *C. splendens* for almost seven (7) decades (Figure 2). In Tanga Region, the cases of presence of expanding populations of the bird increased slowly between 1954 and 2013. From 2013, the cases of such interactions in the region has been increasing at an increasing rate, suggesting a high population number of birds in the area probably due to the successful colonization of the new habitat and lack of natural predators. In Dodoma Region, the no any bird was observed between 1954 and 2017 (Figure 2). The first report of the presence of birds in Dodoma region was registered in 2017. Following these facts, communities in Tanga Region would have more experience with the bird species than the communities in Dodoma Region.

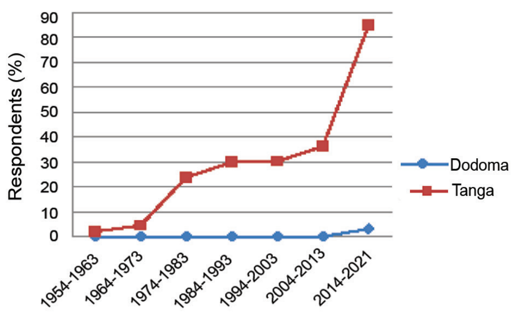

Figure 2. Years of interactions between Corvus splendens and communities in the two regions

Focused Group Discussion

Focus Group Discussion was useful in gathering more detailed information about the impact of the bird species to communities in the two regions. In each of the FGD, the groups were split based on sex in order to allow each sex category to express their personal view concerning the impact of these birds following the method applied by Nyahongo *et al*.,(2009). During the discussion, one female respondent from Chumbageni Street, in Tanga Region, claimed that the birds were used by witch doctors to steal women's underwear most of whom were men. She claimed further that when a witch doctor received the victim's underwear he would use it to make a medicine allowing him to get into the victim's room at night to rape her. This is what is mythically known in Swahili as "*popo-bawa.*" Another female respondent from the same region claimed that she had hung her underwear in the toilet located outside her house. She explained further that when she went in the toilet to take her underwear, she did not find it but later saw it hung on the doorpost of her neighbour who she had quarrelled with the previous day. In this case, she believed that the bird had been sent by her enemy to take her pants for superstitious activities. Unfortunately, the rival did not assent to be interviewed. When asked if she collected her pants back from the doorpost of her rival, she declined by saying:

> *"How could you go and pick the pants from your rival's house? It was obvious that she had consulted a witch doctor to make my husband divorce me because she (the rival) was always jealous of our successful marriage".*

Men were also interviewed in their groups. When asked about the impact of birds to communities, a man from Msalato explained how he lost his money inside his house. The money was taken by the bird. He explained:

> *"We are only two people in my house; my wife and I. I am a businessman who buys cattle and slaughter them each Saturdays at Msalato Market. I remember one morning; I counted six hundred thousand shillings (about USD 252) and placed the money on the table in the living room. I went in bathroom located just outside my house to take shower. My wife was busy outside the house preparing breakfast for me. After taking shower, I came back to the living room to collect my money but did not find the money. My money was stolen; the only capital I had. In the beginning, I believed that my wife was the thief who took the money. I asked her but she declined to take the money. I bit my wife to return my money but she could not bring the money back. While still holding my wife to punish her more, this bird you asked me about (Corvus splendens) got into the living room through the window and picked another 10,000 note that had separated from the rest. From there I knew that the bird was responsible for the total amount missing, and had regretted to punish my wife*."

In one group of female, a positive perception was registered. One respondent from Tanga had a positive perception towards the birds because one day the bird dropped a gold necklace that was probably picked by the bird from another household. To her, the bird was considered a gift giver and hence the "*god of gift*".

She said:

> *"I like the bird because one day when I was out going to buy meat at the nearby butcher, I saw a bird dropping something in front of me and I hesitated to collect it in the first place because before that day I used to think that the bird is always carrying dirty and rotten things. But when I was close to the dropped object, I saw small purse and I picked and opened it just to find a gold necklace! I considered myself lucky that morning and realized that the god of gift lured me for the best walk that morning."*

DISCUSSION

The findings that are reported in this section were obtained directly from the interviewed respondents. Thus, their perceptions and attitudes towards the birds may base on their interactions with the bird species over a long period. Communities in Tanga Region had been interacting with the birds for a longer time compared to communities in Dodoma Region (Figure 2) because the location of the region is close to Zanzibar Island where the birds were firstly introduced in the late 1880s. Thus, when the birds crossed the ocean to mainland, it was easy to colonize coastal regions before expanding to other places. Hence, chances are there that long term experience has shaped both perceptions and attitudes of communities towards the birds. Accordingly, it is not surprising for communities in Tanga Region to hold more negative perception and attitude toward the birds than the communities in Dodoma Region.

The general feeding behavior of *C. splendens* makes it easier for its presence in the environment to be noticed by communities. The birds are known to be aggressive and hence chase other birds from the source of food and water, causing electric shock when stop on live electric wires, contaminating water, annoying communities and polluting water sources (Cooper, 1996). They have been reported to attack and feed on chicks and eggs of other birds. Thus, become lethal to conservation of biodiversity (Csurhes, 2010, Chongomwa, 2011).

Despite the fact that the two regions did not differ significantly on perceptions towards the birds, few respondents showed positive perception regarding the benefit they obtained from the birds (Table 4). One respondent claimed to pick a gold necklace drop by the birds, for livestock keepers, they claimed the useful of the birds in picking ticks from the cattle hence reducing the cost of spraying acaricide to kill ticks from body of livestock. When the money was stolen from the businessman at Msalato, it is obvious that the bird, after realizing that the money was not edible, would have dropped that bunch of money somewhere and picked by somebody else. Later would be happy with the bird and hence having positive perception and attitude towards the bird. In Tanga communities consider birds as alarm watches to wake them up early in the morning as they are always gregarious and become noisy early in the morning. Some respondents claimed that the birds are responsible for cleanliness of the environment through feeding on household leftovers and carrions. Similar observation is reported elsewhere (Król & Hernik, 2020).

When explaining the variation among interviewed individuals on the social impact of the birds to communities, some respondents claimed that the birds were used by witch doctor for superstitious issues. One female respondent sadly discussed about the underwear picked from her toilet and dropped to her rival's doorpost. Since the birds were relatively new to their environment, and because they had not evolved with these introduced birds, individual people like this respondent, may not understand the natural or artificial behaviour of these birds. Likewise, the introduced species in the environment also may not find their natural types of food and hence may just pick anything similar to what they consider as their natural food by its appearance and colour, just to find that they are picking the wrong things. Hence, without awareness education to the communities like this, on the general behaviour of these birds, such communities will always accuse the bird species of being used by witch doctors to steal things for witchcraft ends. This observation is reported elsewhere (Król & Hernik, 2020) that house crows were believed to be symbolic, threatening and being used in rituals.

In most cases, such kind of interactions that pose negative or positive perceptions and attitudes towards *C. splendens* might be exaggerated or under-exaggerated. This is especially when the birds had caused multiple problems like stealing food and materials from the households, attacking and killing livestock and destroying crops, contaminating water sources and dropping rotten materials in the house as reported by respondents in the two regions. Similar observations have been reported elsewhere regarding the above findings (Ntuli et al., 2019).

CONCLUSION

The current study found that local people from both regions of Dodoma and Tanga do not like *C. splendens* because the birds cause problem directly to the communities and to the environment. Only few respondents reported some benefits of the birds to communities especially to livestock keepers and cleanliness of environment. The study revealed that the birds affect more female than males due to the fact that females engage more in household cooking activities which attract *C. splendens*. Some members of communities hold strong belief that the birds are used by witchdoctors to harm other members of communities. This belief is evolving due to lack of awareness on bird's behaviour. Finally, the perceptions and attitudes of the respondents towards the bird in the two study areas were shaped by the duration the respondents had been interacting with the birds (spatial-temporal variations).

RECOMMENDATIONS

The study recommends the followings:

i. It is recommended that sustainable and ecologically suitable *C. splendens* population control measures such as the application of biological procedures be sought.
ii. Education to communities and public awareness about the socio-ecological impact of the bird species should be conducted in affected areas.
iii. It should be included in primary and secondary schools curricula the identification techniques and management of invasive species.
iv. There should be a strict policy developed to control and manage the introduced invasive species such as *C. Splendens*.

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Industrialization, Inclusive Green Growth, and Shared Prosperity Can Tanzania attain a Win - Win Solution without Compromising Biodiversity? A Theoretical Review

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ABSTRACT

This paper went a long way to show how industrialization, inclusive green growth, and shared prosperity could be sustained in Tanzania without compromising biodiversity. The big question in this regard is whether the kind of industrial policy agenda that Tanzania has pursued over the last two decades is associated with "inclusive green growth" and 'shared prosperity'. The main objective of this paper sought to shed light on the extent to which industrialization, inclusive green growth, and shared prosperity could be sustained in Tanzania without compromising biodiversity. Specifically, the paper sought to first, examine how industrial policy takes on board issues of inclusive green growth and shared prosperity; and secondly assess the extent to which Tanzania's industrialization addresses issues related to biodiversity and the environment in a way that is holistically and sustainable. The methodology that was employed by this study was a documentary review of various documents that address issues of industrialization, inclusive green growth, and shared prosperity. In particular, a review of publications by the World Bank occupied a central place. Key results emanating from this study point out that the industrial policy framework agenda neither did it address 'inclusive green growth' nor 'shared prosperity'. The industrial policy framework agenda addresses economic growth concerns at the expense of green growth concerns that acknowledge the role of natural capital growth and its important role in the welfare of future generations. Conclusively, to attain a win-win scenario without compromising biodiversity and the environment at large, the industrial policy framework agenda will have to be reviewed with a view to mainstreaming 'inclusive green growth' and 'shared prosperity'.

Keywords*:* Biodiversity, Environment, Industrialization, Inclusive Green Growth, Shared Prosperity.

INTRODUCTION

Industrialization is marked by the establishment and implementation of a Sustainable Industrial Development policy with the goal of having an industrial sector that is geared toward human development and job creation, economic transformation for achieving sustainable economic growth, environmental sustainability, and equitable development. Industrialization has been the main policy agenda for Tanzania and is considered indispensable for realizing Tanzania's ambition to become an upper-middle-income economy (Martorano *et al*., 2017).

The concept of 'inclusive green growth' should be understood against the background of the current non-green and non-inclusive growth of the world economy. Climate change, ecosystem degradation and resource depletion are threatening the basis of life (IPCC, 2014). Despite the fact that the growth of the world economy has greatly enhanced prosperity and reduced poverty, inequality has risen and the number of people hungry has stayed largely the same (UNEP, 2011). Although the discussion is ongoing on how long the depletion of our natural environment can continue without major economic consequences, it is clear that at a certain point in time climate change, ecosystem collapses, depleted resource stocks, or a combination thereof, will backfire at humanity with enormous social and economic costs (Ostry *et al*., 2014), making the welfare risks of non-green and non-inclusive growth increasingly high. The concept of 'inclusive green growth' acknowledges the trade-offs between growth, green, and inclusiveness, but stresses that in the overarching objective of social welfare, there is room for synergies. Production growth that is environmentally and socially sustainable enhances the welfare most, as environmental degradation and increasing inequality reduce welfare (Economist, 2014). From a welfare-economics perspective, 'inclusive green growth' is nothing more than growth that improves the welfare of both current and future generations and that acknowledges the social costs and benefits (including environmental costs) of growth and its distributional implications in both the short and the long run (IPCC, 2014, Jetske and Ezra, 2015). To this effect, the core meaning of the concept of 'inclusive green growth' can be simply stated as economic growth (growth of gross domestic product or GDP) which also achieves significant environmental protection and takes on board all major sectors of the economy that employ a large spectrum of the active working population.

The main difference between 'growth' and 'green growth' is that the latter acknowledges the role of natural capital in growth and its important role in the welfare of future generations. As has been noted earlier, capital stocks are crucial for growth and development, and, in order for development to be sustainable, current generations should make sure that capital stocks are at least maintained (Dercon, 2012).

Natural capital forms part of the capital stock of a country, so degradation of ecosystems, deforestation, and resource depletion reduce the welfare of future generations if resource rents are not reinvested in alternative capital stocks. When resource rents are reinvested in alternative capital stocks (e.g. human capital or other assets) future generations could inherit a similar amount of capital, and sustainable development would still be ensured. This is called weak sustainability. Strong sustainability requires that future generations not only inherit a similar amount but also that this capital is of similar composition (Neumayer, 2003). This may concern natural capital that is only partly substitutable and sometimes irreplaceable. Dercon (2012) assesses the substitutability of natural capital by concluding that most services provided by natural capital currently are non-substitutable, and if any substitution exists, it is at a very high cost. Although this could change in the future (e.g. a breakthrough innovation that replaces soil formation processes), a precautionary approach may be warranted to safeguard at least a minimum level of natural capital for future generations.

It is important to acknowledge that many of the poorest countries do not reinvest their resource rents and that the over-exploitation of natural capital is often undertaken with foreign direct investments (mining, lumbering, plantations, fossil fuel extraction, and agro-industry) that are facilitated through bilateral, multilateral, and international trade and investment policies (Dercon, 2012). Furthermore, a precautionary approach involves economic opportunity costs, which are especially high for less developed countries, as they tend to have relatively large stocks of natural capital compared to other forms of capital. These opportunity costs need to be taken into account when discussing the protection of global environmental resources, such as biodiversity and carbon stocks (Sen, 1997, Dercon, 2012).

To this end, the main objective of this paper sought to shed light on the extent to which industrialization, inclusive green growth, and shared prosperity could be sustained in Tanzania without compromising biodiversity. Specifically, the paper sought to *first,* examine how industrial policy takes on board issues of inclusive green growth and shared prosperity; and *secondly* assess the extent to which Tanzania's industrialization addresses issues related to biodiversity and the environment in a way that is holistically and sustainable.

MATERIAL AND METHODS

The study employed a documentary review of various documents that address issues on industrialization, inclusive green growth and shared prosperity. In particular, a review of publications on Tanzania's industrialization and industrial policy enriched materials for this paper. Furthermore, materials for inclusive green growth and shared prosperity were also reviewed for the enrichment of this paper. Most of the materials on inclusive green growth and shared prosperity emanated from the publications of the World Bank. Furthermore, publications on biodiversity not only for Tanzanian but also for the global world were equally reviewed. A review of Tanzania's Industrial Development occupied a central place, and in particular, Integrated Industrial Policy 2025 and Industrial Development in Tanzania by Msami and Wangwe (2016) provided substantial information for this study.

Materials from all those publications were descriptively analyzed with a view to shedding light on how Tanzania can attain industrialization, inclusive green growth, and shared prosperity without compromising biodiversity. Essentially, if industrialization, inclusive green growth, and shared prosperity are sustained without compromising biodiversity, a green light for future generations to enjoy the same is guaranteed.

RESULTS AND DISCUSSION

Industrialization

Tanzania lags behind regional role models both in terms of the quantity and quality of industrial goods produced and exported. It continues to rely heavily on the 'less unproductive' agricultural sector, the extractive sector, and 'low' value-added manufacturing. Manufacturing value added is also highly concentrated in a few low-tech sectors, such as food and beverages, hides and skins, and textiles processing industries, making Tanzania's industry vulnerable to international competition. Food and beverages alone account for nearly half of the total manufacturing value added, followed by non-metallic mineral products (11 percent), tobacco (7 percent), and textiles (5 percent). Industrial activity is largely concentrated in Dar es Salaam and coastal regions-more than half of all large manufacturing (Mwang'onda 2018). With respect to industrial policy, the government of Tanzania recognized the leading role the industrial sector would play in the transformation of Tanzania's economy since the first decade of independence. Over the years, efforts were made to liberalize the economy and change the system from a centrally planned economy to a free market economy, encouraging more active participation of the private sector to accelerate growth and increase the nation's prosperity. In this setting and considering the high dependence on post-colonial Tanzania's economy on the agricultural sector, policymakers emphasized the need to build a competitive industrial sector to transform the economy. Since independence, industrial policies have continued to be formulated, as highlighted hereunder, to address the challenges that arise to this very day (URT 2012 and UNIDO 2012):

- *1960 – 1980*: Following independence, the government invested heavily in Tanzania's manufacturing sector, which was virtually non-existent at the time, allowing the sector to grow smoothly throughout the first decade of independence. However, this trend changed dramatically due to a serious economic crisis caused by external shocks and internal constraints during the late 1970s.

- *1980 – 1995*: Sweeping and wholesale trade liberalization, a key ingredient of structural adjustment packages, had a negative impact on the incipient manufacturing sector. Infant industries were particularly affected by the sudden removal of protective trade measures and subsequent massive import flow. Industrial stagnation was further exacerbated by declining agricultural yields and poor product quality. To address the crisis, the government adopted restrictive measures, but it was only in 1986, after the conversion of the economic system from a planned to a free market economy, that the country returned to the path of recovery. While Tanzania's manufacturing sector showed positive signs of revitalization, it faced international competition (mainly from Asian products), which caused several industries to close down.

- *1996 – 2000*: During the second half of the 1990s, the government developed 'The Sustainable Industrial Development Policy (SIDP) 1996-2020', the main purpose being to shift the economy's engine of growth from the public to the private sector, making the latter the key player in spearheading industrial growth and the economy as a whole. The idea in the short run was to consolidate the existing national capabilities in the sector and to build up new capacities in activities with competitive advantages for export markets in the medium term. This phase was characterized by an improved enabling environment, including the provision of fiscal incentives, transparency, a stable and simple regulatory framework, and macroeconomic stability. As a result, the industrial sector started to grow steadily and achieved a high growth rate that was commendable in the 2000s.

- *From 2000 - to date*: Since 2000, consistent economic reforms have transformed Tanzania's manufacturing sector. It got on the track of recovery and has experienced gradual but steady growth due to the acquisition of productive facilities by the private sector and the inflow of foreign direct investment. However, the country continues to be dependent on agricultural and resource-based products with limited value addition. The relevance of the industrial sector has been reflected in many key government policy documents and initiatives of the last decade. Some of these main policy initiatives and development strategies include:

✓ *Tanzania Development Vision (TDV) 2025*: The vision document marks a significant milestone in the era of reform of Tanzania and lays the foundations for the country's new policy framework. TDV explicitly "*aims to transform the nation from a least developed country to a middle-income country by 2025 through the transformation from a weather and market dependent agricultural economy to a self-sustaining semi-industrialized economy*". This shift in focus from an 'agricultural economy' to a 'semi-industrialized' one was essential for the ailing industrial sector of Tanzania. Yet, the failure to put in place a framework for the implementation of TDV 2025 at the inception stage represented the biggest impediment to the attainment of the TDV goals.

✓ *National Trade Policy 2003*: The trade policy was drafted by the Ministry of Industry and Trade and strictly followed the principles stated in the TDV by focusing on private sector-led export growth. The National Trade Policy 2003 emphasized '*stimulation and encouragement of value addition*' as one of its chief objectives.

- ✓ *Small and Medium Enterprise Development Policy 2003*: This policy specifically acknowledged the special role of SMEs in the context of Tanzanian industrialization. It aimed at addressing the constraints to industrialization and to tapping the full potential of Tanzania's SME sector. The policy impact on SME performance, but many constraints existed in the recent past despite the efforts made by the current Government in its industrialization drive.

- ✓ *Tanzania Mini-Tiger Plan 2020*: This plan was introduced in 2005 as an effort to fast-track the implementation of TDV 2025, by replicating the Asian Tiger's models in Tanzania. The plan explicitly states that '*the successful development of the manufacturing sector is the formula that all economically thriving Asian countries followed and it is not an exaggeration to say that the sector's success holds the key to the nation's further development'*. The most important contribution of the Mini-Tiger Plan was the introduction of Special Economic Zones in Tanzania (SEZs) and the plan's focus on export-led manufacturing growth. Unfortunately, the Mini-Tiger Plan failed to attract subsequent attention with the donor community's shift in focus toward the implementation of the National Strategy for Growth and Poverty Reduction (NSGRP).

- ✓ *Export Processing Zones Program*: The program was initiated by the Export Processing Zones Act of 2002, but was formally institutionalized by the creation of the Export Processing Zones Authority (EPZA) in 2006. The objective of establishing EPZs was, among others, the promotion of investment for export-led industrialization, an increase in foreign exchange earnings, an increase in employment, and the promotion of the processing of local raw materials. However, insufficient funds for the development of infrastructure for EPZ/SEZ remain the main constraint for this program.✓ *Long-Term Perspective Plan (2011/12-2025/26) (LTPP)*: The LTPP is the roadmap for the development of three Five Year Development Plans (FYDPs) for the realization of the TDV 2025. The plan is not only restricted to the broad economic transformation of the country but also spells out a detailed industrial transformation path for the country. This clear focus of the LTPP will place industrialization at a central place in Tanzania's future growth agenda.

- ✓ *Integrated Industrial Development Strategy 2025 (IIDS 2025)*: This is the latest initiative by the Ministry of Industry to provide concrete strategies to implement the Sustainable Industrial Development Program (SIDP) objectives in the new economic environment and contributes to the achievement of the goals stipulated in the Tanzania Development Vision (TDV) 2025. Since most of the industrial development strategies proposed in the IIDS touch on multisectoral issues, it is crucial to establish close collaboration and harmonization with other central and sectoral economic authorities, parties and national planning agencies. The strategy highlights the horizontal, vertical, and supporting framework required to create and position a competitive industrial sector based primarily on labor-intensive industries. The targeted sub-sectors specified in the IIDS 2025 are fertilizer and chemicals, iron and steel, textiles, agro-processing, edible oil, processed cashew nuts, processed fruits, milk and milk products, leather and leather products, light machinery, and the hospitality industry. The IIDS 2025 also mentions the necessary policy measures to boost the industrial sector and contribute to the structural change of the economy.

Did Industrial Policies initiated since Independence Address Biodiversity Conservation, Inclusive Green Growth, and Shared Prosperity?

Green growth concerns the welfare of future generations, whereas 'inclusive green growth' is concerned with the welfare of current generations as well as an equitable distribution of welfare gains. It is important to note that there is a difference between equity and equality. Equity refers to initial conditions--all people are equal under the law--while equality refers to outcomes--everybody should earn the same. In the current neoliberal market ideology, the focus is mostly on equity, with equality being regarded as a political aim.

Green growth is not automatically inclusive and inclusive growth is not always green, and it is important to acknowledge that tensions between green growth and inclusiveness exist. The welfare of future generations may require limits to growth for the current generation, but without additional measures, this could especially impact the poor. Similarly, growth and inclusiveness do not necessarily go together, as distributional fairness often conflicts with efficient resource use. This has to be considered--synergies between green growth and inclusiveness may not be possible and additional efforts are needed to balance trade-offs (Dercon 2012).

With respect to shared prosperity as spearheaded by the World Bank refers to an increase in per capita real household income or consumption of the bottom 40 percent of a country's population. Since the goal is country-specific, there is no explicit target set at the global level (World Bank 2014). The tracking of shared prosperity can reinforce poverty reduction efforts in low and lower-middle-income countries by bringing attention to those people not covered by social inclusion policies but who might otherwise be left behind.

Against this background thereof, it is evident that all industrial policies that Tanzania pursued since independence paid very little attention to green growth, inclusive growth, shared prosperity, and biodiversity conservation. For instance, in the early 1960s, the national economic agenda focused on growth with no attention to green growth, biodiversity conservation, and shared prosperity. Nevertheless, green growth, biodiversity conservation, and shared prosperity were not issues of concern during the early times of independence not only for Tanzania but also for the rest of the world.

The coming into force of the Economic Recovery Program in 1986 ushered in a transformation of the economy from one being entirely state-owned to one that involved private ownership of the production process. This saw the establishment of the Tanzania Industrial Development Organization (TIRDO) which aimed at conducting industrial research and offering consultancy services to industries (Msami and Wangwe, 2016). Again, TIRDO did not address issues of green growth, biodiversity conservation, and shared prosperity although consequences of not conserving biodiversity were already eminent.

At this juncture, it should be noted that concepts of green growth and shared prosperity are new for Tanzania. The green economy has emerged recently and has manifested itself in advocating for a holistic and programmatic approach among the three pillars of sustainable development, namely, economy, social welfare, and the environment (Bilame 2020). Currently, Tanzania has no national definition on the meaning of the terms "Green economy" and Green growth". However, different national policies have elements that promote a green economy. Such elements include but are not limited to the promotion of renewable energies (solar, hydropower, wind, geothermal, biogas), use of energy-efficient appliances and equipment, efficient mass transit systems, cleaner production initiatives, fuel switching to natural gas and other alternative energy sources, promotion of energy-efficient cooking stoves and promotion of mini-hydro and co-generation projects (Bilame 2020).

To this end, it is vivid that all the main industrial policy initiatives and development strategies that Tanzania pursued since independence up to the early 2000s did not pay attention to issues of green growth, inclusive growth, shared prosperity, and biodiversity conservation just for one reason that they were not priorities for the nation by that time.

DISCUSSION

Tanzania Industrialization: A Win-Win Scenario for Biodiversity, Inclusive Green Growth and Shared Prosperity

Tanzania's Long Term Perspective Plan (LTPP) is an important vehicle for implementing the Tanzania Development Vision 2025, which emphasizes Tanzania's cherished goal of becoming a prosperous nation by attaining high economic growth through industrialization and thereby eradicating poverty (URT 2012, Tanzania Human Development Report, 2017, Bilame 2017). Thus, the Tanzania's Long Term Perspective Plan seeks to achieve economic growth that will enable Tanzania attain a Higher Middle-Income Country (MIC) status by 2025[1].

The path to realizing TDV 2025 targets is to be facilitated by opportunity-based planning implemented through a series of three Five-Year Development Plans, building on each other and making use of Tanzania's opportunities and addressing the challenges. The socio-economic transformation is planned to be addressed through three strategic Five Year Development Plans (FYDPs) (URT 2012) the First FYDP (2010-2015): *Unleashing the Growth Potential*; the Second FYDP (2016/17-2021/22): *Nurturing an Industrial Economy*; and the Third FYDP (2021/22-2025/26): *Realizing Competitiveness and Industrialization for Human Development*. The linkages between the three plans are crucial, with a view to attaining an Upper Middle-Income Country status. It should be noted at this juncture that in 2015, the Second Five Year National Development Plan with the theme *Nurturing an Industrial Economy* was reviewed in line with the Government's decision to integrate the plan with the National Strategy for Growth and Reduction of Poverty (NSGRP)-in Swahili acronym as MKUKUTA. This move included issues of poverty reduction and improved living conditions which were key issues for MKUKUTA. This led to the revision of the theme of the Second Year Five Development Plan to be *Nurturing Industrialization for Economic Transformation and Human Development.*

As of now, Tanzania is implementing the third FYDP (2021/22-2025/26) with a broad-based strategic plan for *Realizing Competitiveness and Industrialization for Human Development*. However, both the first and second Five Year Development Plans are almost silent on 'inclusive green growth'; the emphasis in both documents is on the socio-economic transformation of the Tanzania economy that is spear-headed by a vibrant industrial sector. In fact, issues of inclusiveness of green economic growth along with sharing prosperity emanating from such inclusive economic growth are not at all addressed by the documents. The main objective of the current third FYDP (2021/22-2025/26) with the broad-based strategic plan on *Realizing Competitiveness and Industrialization for Human Development* is to contribute to the realization of the National Development Vision 2025 goals. Unlike the two previous Five-Year Development Plans that paid little attention to issues of environmental and natural resource management, the third Five Year Plan does take on board issues of environmental and natural resource management. Key interventions and performance indicators and targets for natural resources and environmental protection are clearly spelled out. The interventions, just to mention a few are (URT 2021):

- Promote renewable green energy technologies;
- Enhance environmentally sound management of land resources for socio-economic development;
- Minimize environmental pollution and the resultant adverse effects on the environment and human health; and
- Strength the national capacity for addressing climate change impacts.

To this end, the third Five Year Plan has to a large extent addressed issues of biodiversity conservation because it tresses issues on natural resources and environmental protection. Nevertheless, issues on inclusive green economic growth and shared prosperity are not featured in the third Five Year

Development Plan. The question of concern is *what if socioeconomic transformation is achieved at an expense of non-inclusive green growth and non-shared prosperity?*

Exploring the answer to this question implies nothing more than growth that does not improve the welfare of both current and future generations. An economic growth that does not acknowledge the social costs and benefits of growth and its distributional implications in both the short and the long run cannot attain inclusive green growth and shared prosperity. In the course of reviewing the current Five-Year Plan, it would be of paramount importance to mainstream issues of inclusive greening growth and shared prosperity.

Shared Properity: What are the issues of concern?

The broad focus of the shared prosperity goal is in keeping with the call for development goals that go beyond access to or ownership of material goods. Sen (1983, 1999)-a key proponent--has called for income to be viewed not as the sole end to development but rather as a gauge of what a person is able to do (capability) and manages to do (functioning). This broader perspective of development has been influential in the literature on broad-based growth and has led first to efforts to measure the non-income dimensions of development and then to work on inclusive growth that examines how growth trickles down to the poor. That work, in turn, has led, through the introduction of multidimensionality, to the notion of "inclusive development."

On the other hand, equity is a fundamental building block of shared prosperity. The World Bank Group's institutional objective of promoting shared prosperity targets the bottom 40 percent of the population as an anonymous group irrespective of the identity of its members (World Bank, 2014). This strong focus on the less privileged places equity at the very heart of the goal and the indicator of shared prosperity.

Underpinned by equity, the shared prosperity concept is intricately related to the inequality of opportunity. The World Bank (2013b) highlights that even though the shared prosperity indicator is focused on outcomes, the requirement to pursue shared prosperity in a socially sustainable fashion tie the concept to the promotion of equality of opportunity. This focus is also present in modern theories of social equity, which, like Rawls's, build on Harsanyi's (1955) "veil of ignorance argument": an equitable resource allocation should reflect what all prospective members of society would agree on before they knew which position they would occupy in that society. Accordingly, while modern theories of equity remain concerned that individuals be spared from extreme deprivation in outcomes, they emphasize the importance of ensuring equal opportunities for individuals to pursue a life of their choosing. The outcome of a person's life, in its many dimensions, should reflect efforts and talents, and not predetermined circumstances—such as family origins, race, gender, or place of birth—or the social group a person is born into.

To this end, considering the number of programs, plans, strategies, and initiatives that focus on industrialization that have been introduced by the Government since 2000, one thing becomes quite clear: over the last two decades, industrialization has received more attention in the national development agenda than ever before. However, what matters far more than the 'priority status' of industrialization in policy documents is priority resource allocation and timely, consistent, and effective policy implementation. Unfortunately, the Tanzanian industrial policy implementation is found wanting in several of these crucial factors, although some of the successes in industrial performance can certainly be directly attributed to some of the government's policy interventions described above. For instance, the liberalization agenda the government has diligently followed since the 1990s has paved the way for major investments in several resource-based sectors. At the same time, whether by intent or accident, a number of middle-cadre technical colleges were turned into university colleges or fully fledged universities, denying the country a critical mass that is the core of industrial growth. Clearly promulgated policies result in a zero-sum game if at the time of their promulgation practice is moving in the opposite direction. There is, therefore, considerable room for efficiency gains through policy intervention in the industrial sector.

At this juncture, one is in a position to comment as to whether the kind of industrial policy agenda that Tanzania has pursued over the last two decades is associated with "inclusive green growth" and with 'shared prosperity' with preserving biodiversity. From the earlier discussion in this paper, '*inclusive green growth' has been pointed out to be nothing more than growth that improves the welfare of both current and future generations; that acknowledges the social costs and benefits (including environmental costs) of growth and its distributional implications in both the short and the long run (IPCC 2014, Jetske and Ezra, 2015). Furthermore, the core meaning of the concept of 'inclusive green growth' can be simply stated as economic growth (GDP growth) that also achieves significant environmental protection and takes on board all major sectors of the economy that employ a large spectrum of the active working population*.

Shared prosperity, as has also been highlighted in this paper, recognizes the pursuit of well-being among the most vulnerable in society (Narayan *et al*. 2013). Thus, *shared prosperity requires well-being to be shared across individuals over time. This multidimensional aspect of the goal points to the need for a focus not solely on income, but also on non-income dimensions of prosperity such as education, health, nutrition, and access to water and essential infrastructure, as well as on enhancing the voice and participation of all segments of society in the economic, social and, political spheres (World Bank 2013b)*.

From the onset of the industrial policy framework agenda, one can easily and vividly comment that the policy neither addressed 'inclusive green growth' nor 'shared prosperity'. The industrial policy framework agenda addresses economic growth concerns and not even green growth concern that acknowledges the role of natural capital growth and its important role in the welfare of future generations. Neither also did the industrial policy framework agenda address conservation of biodiversity concerns. As has been discussed earlier in the preceded sections, issues on green growth, inclusive green growth, and shared prosperity are current topical issues that are spearheaded by the World Bank and developed nations and are indeed called for by each country. That effect, it was the right time for Tanzania to mainstream issues of green growth, inclusive green growth, and shared prosperity in all policy documents and any development endeavors projects, and programs.

CONCLUSION

Based on the discussion that has preceded, various policy documents that include but are not limited to the Third Five Year Development Plan (2021/22-2025/2026) and the Long Term Perspective Plan for 2011/2012 - 2025/2026 will have to be reviewed with a view to mainstreaming 'inclusive green growth' and 'shared prosperity.' It is vivid that industrial policies that were formulated and implemented since independence paid very little attention to issues of biodiversity conservation, green growth, inclusive green growth, and shared prosperity. As pointed out earlier, issues on biodiversity conservation, green growth, inclusive green growth, and shared prosperity are recent topical issues and from the time of independence, all along to the 2000s were not critical issues of concern except for biodiversity issues that started to emerge as critical during the early 1990s. Green growth, inclusive green growth, and shared prosperity are recent topical issues that are being spearheaded by the World Bank; but since they are meant to bring about the welfare of people in each country if they are put in place; then they should be mainstreamed in different policies of each and every country in this world. Since Tanzania is not an isolated island, she should mainstream issues of green growth, inclusive green growth, and shared prosperity in all her policies with a view to attaining sustainable development-a development that takes care of not only the benefits of the current generations but also the benefits of the future generations.

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COVID-19 PANDEMIC AND ITS SOCIO-ECONOMIC EFFECTS ON LOCAL COMMUNITIES ADJACENT BURUNGE WILDLIFE MANAGEMENT AREA, TANZANIA

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ABSTRACT

Coronavirus-caused COVID-19 has various effects worldwide. The purpose of this research is to analyse the socio-economic effects of Covid-19 on local communities adjacent to the Burunge Wildlife Management Area (WMA). A questionnaire survey, group discussion, and key informant consultation were conducted on a total of 102 respondents, of whom 55.9% (n=57) were male and 44.1% (n=45) were female. The socio-economic practices of the respondents included traditional and handcrafted product businesses (10.8%, n=11), agriculture (29.4%, n=30), livestock keeping (13.7%, n=14) and other small-to-medium enterprises (SMEs), including restaurants and shops (19.6%, n=20). Among the respondents, 93.1% (n=95) agreed that the occurrence of COVID-19 affected their socio-economic activities. Among the effects pointed out by respondents were losing jobs (10.8%, n=11), a massive decline in the number of customers (96.1%, n=98) and deflation resulting in low revenue (96.1%, n=98). Across the study villages, alternative activities offered and implemented by local communities during COVID-19 included agriculture (27.5%, n=28), fishing (11.8%, n=12) and handcraft (4.9%, n=5). It is important to provide local communities with alternative sources of income that are environmentally, economically, and socially sustainable, such as beekeeping, agro-production, and fish farming.

Keywords: Alternative income, Burunge WMA, COVID-19, Local communities, Socio-economic effects.

INTRODUCTION

The globe was plunged into darkness in December 2019, when the first case of coronavirus disease (COVID-19) caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) was announced in Wuhan, China (Neupane, 2020). On March 11, 2020, the World Health Organization (WHO) officially declared COVID-19 a global pandemic (Neupane, 2020). The COVID-19 pandemic had a wide range of effects worldwide. Individual economies were aggravated by the enforcement of lockdowns, travel bans, and social isolation, while the economics of afflicted countries suffered substantially more than at any time in the preceding visible years (AUC, 2020; World Bank, 2020). According to the FAO (2020), the socio-economic sector has been severely impacted by COVID-19. Agricultural activities, education, health, small-to-large enterprises, and other divisions in this paradigm became stuck during the COVID-19 crisis, to the point where their normal operations and setups were severely disrupted.

The tourism sector is no exception to the adverse consequences of the COVID-19 pandemic (AUC, 2020; UNWTO, 2020). Many protected areas experienced numerous problems in achieving their stated objectives, particularly during the period when social isolation, lock-down, and travel restrictions were imposed by various countries throughout the world (AUC, 2020). The loss of around 300 to 450 billion US dollars in 2020 compared to 2019 worldwide, as reported by the World Tourism Organization, roughly depicted the magnitude of the effects of the COVID-19 pandemic on the tourism sector (UNWTO, 2020). The COVID-19 pandemic has put the existence of protected areas in jeopardy. According to Bennett *et al.* (2020) and McGinlay *et al.* (2020), illicit activities such as poaching and illegal logging (deforestation) have increased dramatically within and around protected areas (Hockings et al., 2020). Furthermore, many protected areas were also exposed to farmland expansion and encroachment for cattle feeding, which may have resulted in unfavourable land cover and pattern alterations for wildlife (IUCN, 2020).

COVID-19 had negative impacts on Wildlife Management Areas (WMAs) in Tanzania, as it has on other types of protected areas (Shoo *et al.,* 2021). For instance, the Burunge WMA authority (JUHIBU) reported that, the COVID-19 pandemic has resulted in an income drop of approximately TZS 1,362,537,656 in 2019/2020 to TZS 476,740,689.00 in 2020/21 (USD 587,680.67-205,624.62). Because of their reliance on tourism activities, the consequences were felt not only on their management, but also on the livelihoods of nearby local residents (Shoo *et al.,* 2021; Spenceley *et al.,* 2021). Local communities in the area were involved in a variety of social and economic activities that relied heavily on the respective Wildlife Management Areas (WMA) for a living. Soon after the outbreak of the COVID-19 pandemic, the story turned upside down, with the destruction of the market for their commodities, deflation resulting in low income, job losses, and a significant drop in the number of customers clouding their daily earnings and dragging them into difficult times of struggling for their livelihoods (Manenti *et al.,* 2020; Shoo et al., 2021).

Despite efforts to better understand the impacts of the COVID-19 pandemic on indigenous and local communities living near protected areas, little is known about the extent to which these impacts changed or modified the communities' patterns and livelihoods, particularly for those who rely on protected zones. Furthermore, there is insufficient information on the alternative sources of income that supplement local communities' income during the COVID-19 pandemic. This inadequate knowledge necessitates additional research on the aforementioned challenges for the benefit of the protected areas, as well as indigenous and local communities adjacent to these areas. The objective of this study was to learn more about the socioeconomic consequences of Covid-19 on the local populations surrounding the Burunge WMA, as well as the alternative livelihoods that were used for survival during the crisis. This study is critical because it provides baseline information on the severity of the COVID-19 pandemic's impacts on the socioeconomic sector while also highlighting various alternative sources of income used by local populations near protected areas during this time. The findings of this study will aid responsible bodies and local communities in devising various methods and plans to mitigate the effects of unanticipated disasters such as COVID-19 and modify some policies in the interest of protected areas and neighbouring local communities.

MATERIALS AND METHODS

Study area

The study was conducted in three purposively selected villages: Minjingu, Ngolei and Mwada, which form the Burunge Wildlife Management Area (WMA) within the Tarangire-Manyara Ecosystem (TME). These villages were selected because of their direct or indirect reliance on the Burunge WMA in a variety of ways, including their potential to benefit from tourism activities within and around the protected area. The Burunge Wildlife Management Area (WMA) is 617 square kilometres in size, with 280 square kilometres set aside for wildlife. It is found in the Tarangire-Manyara Ecosystem (3.94°S to 3.66°S and longitude 35.73°E to 35.97°E) in the Babati district, Manyara region (Fig. 1) (Kiffner *et al*., 2020; WWF, 2014)communities can set aside land and formally register it as Wildlife Management Area (WMA. The Burunge Wildlife Management Area (WMA) receives between 400 and 500mm of rain per year, with alternating seasons of dry, long, and short rains, with temperatures ranging from 180°C to 330°C. The area is dominated by riverine vegetation, Acacia woodlands, and edaphic grasslands at an elevation of approximately 1,000m. The ethnic groups found around the Burunge Wildlife Management Area (WMA) are Maasai (pastoralists) and Mbugwe (agro-pastoralists) (Kaswamila, 2012).

Study design

The study population was drawn from three carefully chosen communities in the Burunge WMA area. A sample of at least 5% of the entire population was selected for this study (NIST, 2020), this making a total of 102 respondents (Minjingu = 33, Mwada = 43, and Ngolei = 26). To ensure simple access to essential information, the positions and their title functions were employed as criteria for selecting key informants. Village government leaders greatly helped in the process of selecting members of the local communities to participate in the study from selected villages, using random sampling techniques. The community members who participated in the study benefited directly or indirectly from different activities taking place within and around the WMA, including tourism. The gender of respondents was considered to obtain a variety of perspectives, understandings, and knowledge

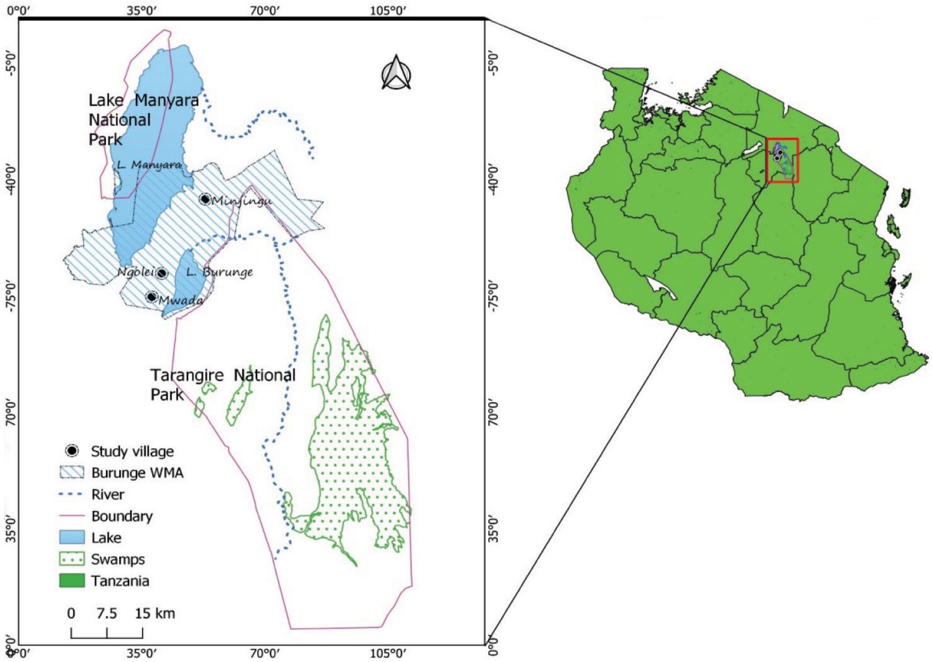

Figure 1. Map showing the three study villages (Minjingu, Mwada, and Ngolei) which form the Burunge Wildlife Management Area (WMA) within the Tarangire-Manyara Ecosystem (TME)

of the subjects. The information needed was gathered through semi-structured surveys, interviews, and focus group discussions. The study's questionnaires were expected to yield a variety of data, including geographic data, socio-demographic statistics, and respondents' socio-economic activities.

Data collection

House hold survey

Semi-structured questionnaires were used to collect information about the respondents' socioeconomic activities. Additionally, the administered questionnaires were designed to gather further information on how the COVID-19 pandemic affected or disturbed their lives in comparison to the time preceding the outbreak. Respondents were also asked to estimate customer trends and revenues earned during the COVID-19 pandemic.

Focus group discussion

A Focus Group Discussion (FGD) was also held with groups of at least four respondents to gain a broad and deeper understanding of the problem under investigation. Participants were asked questions on the alternative sources of income to replace their COVID-19-interrupted careers, as well as to identify them according to their preferences and priorities.

Data analysis

The collected data were coded, classified, and collated using Microsoft Excel® (Microsoft Corporation, Washington, USA). The analysis was then performed using SYSTAT (Version 13.2 Inc. 2017) (http://www.systat.com) with a significance level of 0.05. A Kruskal-Wallis statistical test was employed to assess data relating to socioeconomic position as a result of the COVID-19 pandemic's impact on local communities, as well as alternative sources of income adapted as a means of survival during the pandemic. A Kruskal-Wallis statistical test was used because the data showed non-parametric patterns. Descriptive statistics, such as mean, percentage, and cross-tabulation were also used. Tables and graphs were used to present a lot of information about the analysed data in a readable and easy-to-understand manner.

RESULTS

Socio - demographic profile of respondents

A total of 102 respondents from three study villages (Minjingu, Mwada and Ngolei) were interviewed. Out of all, 55.9% (n=57) were males and 44.1% (n=45) were females. The percentage of female respondents was higher in Mwada and least in Minjingu. In case of male respondents, Minjingu had large number followed by Ngolei whereas the least number was recorded from Kakoi village (Table 1). The variation among gender distributions in the three villages was significant ($P < 0.01$). Moreover, age wise, youths contributed majority of the respondents whereas old group had a least number of respondents across all study villages, with the variation being not significant ($P = 0.7$) (Table 1). The education level of respondents was also recorded, with 51.0% (n=52) having primary education, followed by secondary education (34.3%, n=35), tertiary education (8.8%, n=9) and informal education (5.9%, n=6). The variation in education level among the participants across the three study villages was not significant ($P = 0.07$) (Table 1).

Table 1. Socio-demographic characteristics of the respondents in the study villages

S/n	Variable	Categories	Minjingu % (n=33)	Mwada % (n=43)	Ngolei % (n=26)	P
1	Gender	Female	24.2(8)	62.8(27)	38.5(10)	< 0.01
		Male	75.8(25)	37.2(16)	61.5(16)	
2	Age	18-40 (Youth)	75.8(25)	81.4(35)	84.6(22)	0.70
		41-60 (Adult)	21.2(7)	16.3(7)	11.5(3)	
		> 60 (Old)	3.0(1)	2.3(1)	3.8(1)	
3	Education level	Informal	6.1(2)	2.3(1)	11.5(3)	0.07
		Primary	60.6(20)	41.9(18)	53.8(14)	
		Secondary	24.2(8)	44.2(19)	30.8(8)	
		Tertiary	9.1(3)	11.6(5)	3.8(1)	

Source: Field data, 2021.

Socio-economic characteristics of the respondents

The socio-economic activities were agriculture (29.4%,n=30), handcrafting activities (10.8%, n=11), small-to-medium enterprises (19.6%, n=20), livestock keeping (13.7%, n=14), fishing (10.8%, n=11) and some were employed in different sectors (15.7%, n=16). The variation in socio-economic activities across the villages was not significant (P = 0.15) (Fig. 2).

In Minjingu, they were farming (12.1%, n=4), fishing (33.3%, n=11), Small-to-medium enterprises (18.2%, n=6), handcraft (18.2%, n=6), livestock keeping (9.1%, n=3) and employed (9.1%, n=3), whereas 39.5% (n=17), 11.6% (n=5), 32.6% (n=14), and 16.3% (n=7), for farmers, livestock keeping, small-to-medium enterprise and employed respectively in Mwada village while farming dominated in Ngolei with 34.6% (n=9), livestock keeping (23.1%, n=6), employed (23.1%, n=) and handcraft (19.2%, n=5).

Socio-economic activities versus COVID-19 pandemic

Of the 102 respondents, 93.1% (n=95) were affected by the COVID-19 Pandemic. The three main impacts were the decline in the number of customers reported by 96.1%, (n=98) of respondents, losing jobs (10.8%, n=11) and deflation causing low income (96.1%, n=98), each being calculated separately from the total number of respondents. In this case, 90.9% (n=30), 100% (n=43) and 96.2% (n=25) from Minjingu, Mwada and Ngolei respectively, experienced a decline in customer numbers which was not significant across the villages (P = 0.13), and 96.2% (n=25) from Ngolei, 90.9% (n=30) from Minjingu and 100% (n=43) from Mwada faced the decline in income with the variation being not significant among the villages (P = 0.13) and job loss were experienced by Mwada (23.3%, n=10) and Minjingu (3%, n=1) which was significant (P< 0.01) across the study villages (Table 2).

Table 2. Impact of COVID-19 on socio-economic activities

Variable	Responses	Minjingu % (n=33)	Mwada % (n=43)	Ngolei % (n=26)	P
Decline in number of customers	NO	9.1(3)	0	3.8(1)	0.13
	YES	90.9(30)	100(43)	96.2(25)	
Decline in income	NO	9.1(3)	0	3.8(1)	0.13
	YES	90.9(30)	100(43)	96.2(25)	
Losing jobs	NO	97(32)	76.7(33)	100(26)	< 0.01
	YES	3(1)	23.3(10)	0	

Source: Field data, 2021

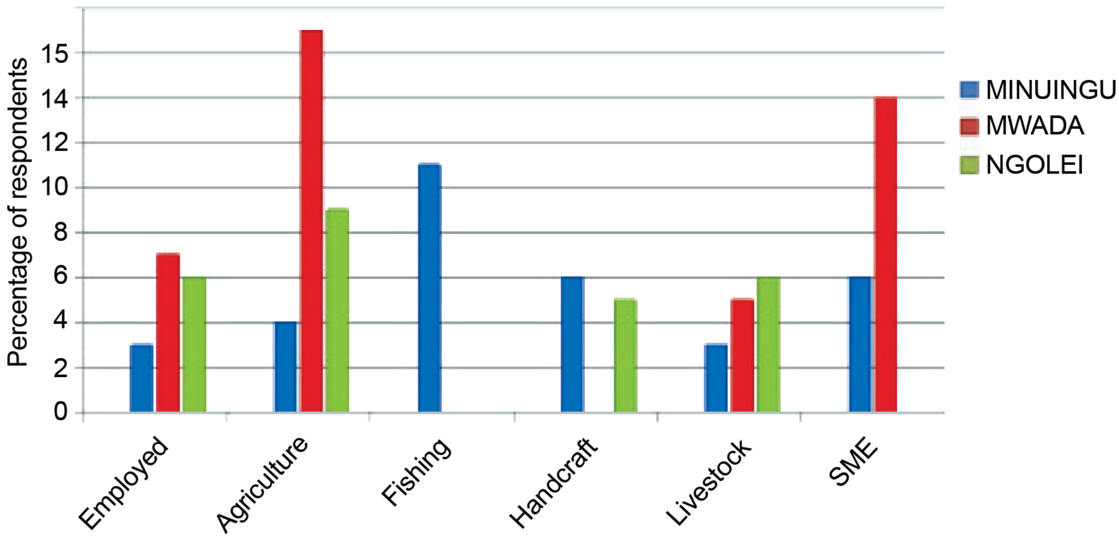

Figure 2. Socio-economic activities of respondents in three study villages (Source: Field data, 2021)

Alternative sources of income during the COVID-19 pandemic

Agriculture (27.5%, n=28), boda boda (Motorcycle taxi) (3.9%, n=4), fishing (11.8%, n=12), handcrafts (4.9%, n=5), livestock keeping (25.5%, n=26), restaurants (2%, n=2), shops (3.9%, n=4), and vendors (1%, n=1) were among the alternative sources of income identified by respondents, whereas 19.6% (n=20) had no alternative sources of income (Table 3). The respondents showed some variations in this category whereby, at Minjingu village, the dominated alternative sources of income were fishing, agriculture, and handcraft (Table 3). In case of Mwada and Ngolei, agriculture and livestock keeping were reported to be dominant out of other socio-economic activities in the two villages. Restaurants, shops, vending activities and boda boda (Motorcycle taxi) were among the least performed socio-economic activities across the study villages (Table 3). The variation in alternative sources of income during the COVID-19 pandemic across the villages was significant (P = 0.02) (Table 3).

Table 3. Alternative sources of income adapted by respondents during COVID-19

Variable	Minjingu % (n=33)	Mwada % (n=43)	Ngolei % (n=26)	P
Agriculture	15.2(5)	44.2(19)	15.4(4)	
Boda boda (Motorcycle taxi)	0	7(3)	3.81(1)	
Fishing	30.3(10)	0	7.7(2)	
Handcraft	12.1(4)	2.3(1)	0	0.02
Livestock keeping	12.1(4)	30.2(13)	34.6(9)	
Restaurants	3(1)	2.3(1)	0	
Shops	0	4.7(2)	7.7(2)	
Vendors	0	0	3.8(1)	
No alternative	27.3(9)	9.3(4)	26.9(7)	

Source: Field data, 2021.

DISCUSSION

Socio-demographic profile of respondents

In this study, male participants outnumbered females by 11.8%. The observed slight deviation was due to the fact that males are the heads of households and decision-makers in the majority of African cultures (George *et al*., 2016); thus, they participate in different situations demanding suggestions, opinions, or any other contribution. Many respondents were between the ages of 18 and 40 years (youth category). Mwada village had a considerable number of individuals belonging to the youth age group compared to other study villages, with the variance in age group distribution across them being insignificant. The findings reveal a modest variance in age group patterns throughout the research sites. It is in this age group (youth) that individuals are economically active, productive and capable of conducting different socioeconomic activities for their lives and livelihoods, as stated by URT (2006). Primary school leavers made up the majority of the participants, with secondary school graduates coming in second. This variation indicates that most of the individuals who are engaged in different activities, including agriculture, livestock keeping and fishing in local communities adjacent to the protected areas are those with a basic level of education, as it is common in many farmers' and pastoralists' families (Sigala *et al*., 2021). These findings suggest the need to empower and educate young people for the sake of conservation and sustainable livelihoods for their lives and society as a whole, as corroborated by previous studies (Morar & Peterlicean, 2012; Nadeson & Barton, 2014).

Socio-economic characteristics of the respondents

The findings in this study showed that most of the local people near the Burunge WMA were conducting diverse activities, but agriculture, fishing and livestock keeping were the primary means of earning cash. Socio-economic activities changed only slightly among the three villages. For instance, most of the households in Mwada village are farmers, whereas those in Minjingu and Ngolei are active in fishing and livestock raising respectively. The variation observed between the socio-economic statuses of the three study areas was probably influenced by several factors, such as the ratio of a certain age group over the other, the availability of land for agriculture and pastures and the proximity of a particular village to the protected area. This is consistent with other research conducted in villages around protected and conserved areas (Kaswamila, 2009; Moshi 2016). For instance, research conducted by Kaswamila (2009) in the Esilalei, Barabarani, and Migombani communities within the Tarangire-Manyara ecosystem found that the predominant socio-economic activities in these areas are subsistence farming, livestock raising, and other tourism-based activities. Furthermore, a study conducted in villages near Saadani National Park (SANAPA) revealed that many indigenous and local communities located near protected and conserved areas rely primarily on agriculture and livestock husbandry, and the observed variation among these villages is driven by the size of the local people's landholdings and the proximity of the individual villages to the parks (Moshi, 2016).

Effects of COVID – 19 pandemic on socio-economic activities

All three study villages experienced the agony of the COVID-19 outbreak in their socioeconomic activities. The research discovered that the local communities situated near the protected areas experienced numerous challenges, including a reduction in the number of consumers and deflation, resulting in reduced revenues in almost the same range across the villages. It was further noted that in Mwada village, the number of individuals who had lost their occupations was higher compared to the other studied sites. The reason behind this was the total reliance of local communities on the tourism sector and other WMA linked enterprises. Similar findings have been reported in various countries and worldwide. For instance, a study conducted in five selected WMAs showed that nearly all the tour guides at Ikona WMA lost their jobs due to the COVID-19 pandemic, while the same was observed in Enduimet, Randilen, Burunge and Makao WMA where some employees, especially those paid by the villages, were given leave without being paid their salaries while others were working on loans (Shoo et al., 2021). Other findings in Malawi have shown that a large number of indigenous and local populations engaged in farming, fishing, and bee-keeping suffered greatly as a result of COVID-19. The fall in tourists in protected areas in Malawi due to COVID-19, who were the main clients of honey and other products, led to a drop in sales in the market, thereby adversely affecting their livelihoods (Attah, 2021). In addition, a study conducted by (Kideghesho *et al.,* 2021) indicated that the majority of people operating in the informal sector around protected zones had lower market, demand, and total sales of their items.

Alternative sources of income during the COVID-19 pandemic

As a strategy for survival during the COVID-19 pandemic, local populations had to seek new ways of generating revenue for their survival. In Minjingu, Mwada and Ngolei villages, residents turned to other alternative means of income, including agriculture, fishing, and livestock keeping, while others involved with boda boda (Motorcycle taxi) driving, restaurants and other businesses to name a few. Other people had no alternative source of income; the circumstance that was mentioned by FAO (2020) forced people to transgress various norms so as to survive. The study indicated that the aforementioned activities caught the interest of many because they were the only possible means of earning income for the indigenous and local people adjacent to the protected zones during the COVID-19 crisis. Moreover, these tasks were among the familiar traditional socio-economic activities undertaken by many individuals ever since, so switching to them was accompanied by some past experience, making them easier to take and operate. The study found that, due to the impact of COVID-19 on the market and other factors, the quantity of revenue generated through these activities was insufficient to meet all basic needs of the families. Intensive agriculture and livestock husbandry, the two main alternatives, are likely to damage natural habitats and impede wildlife growth (Seki et al., 2018). These findings correlate with a study conducted by (Kideghesho et al., 2021), which found that many people fled from urban regions to rural communities in search of alternative livelihoods, particularly those working in the informal sector in urban areas during the COVID-19 crisis. A further increase in population due to urban-rural movement and a lack of diversification of economic options in villages may hasten the prevalence of poaching, deforestation, and other illicit activities (Kideghesho et al., 2021). This is supported by several studies that have revealed the tight linkage between insufficient diversification of sources of income by people and fraudulent activities within or surrounding protected areas (Knapp, 2012; Loibooki et al., 2002).

Implication in biodiversity conservation

Like an alert, COVID-19 highlighted how resilient protected areas are, not only in Tanzania but also internationally. The COVID-19 pandemic has led to very difficult repercussions for both protected areas and local residents, depending on various activities taking place around them. The findings revealed that some residents worked in the tourism sector, while others participated in various informal socio-economic activities within and around the WMA to earn a living (Shoo *et al*., 2021). The disruption of the tourism sector therefore induced some difficulty in handling many situations in protected areas and the adjacent local communities, which endure many wildlife conservation challenges, especially by delegating their pieces of land for conservation and tolerating human-wildlife conflict all year long. The shift of local communities into alternative sources of income as observed in the study marked the beginning of a new chapter on wildlife protection, especially after identifying that agriculture, fishing and livestock keeping among others, are the top alternative sources of income adapted by communities during the COVID-19 juncture. By examining the implications of these activities on natural habitats and a variety of species (Seki *et al*., 2018), there is a need to create numerous techniques and strategies to limit their impacts on biodiversity in general. As highlighted by Ellis (2000), the data revealed the necessity of the local community to have diversified sources of income that are socially and environmentally benign, rather than relying only on tourism activities to avoid potential anticipated impacts on biodiversity.

CONCLUSION AND RECOMMENDATION

The outbreak of the COVID-19 pandemic has resulted in various detrimental consequences in different sectors worldwide. The wildlife sector was also hit by the repercussions of COVID-19, whereby the implementation of several operations inside the protected areas and the participating communities was interrupted. The impacts were not observed just within the protected areas management, but also prevailed in the local communities adjacent to the protected areas. Unpreparedness to respond accordingly during COVID-19, due to the lack of diversified means of revenue, made the socioeconomic position of the members of the specific communities worse. As a strategy for survival, many people turned mostly to agriculture, livestock keeping, and fishing pursuits for the sake of their lives. Due to a lack of alternative sources of income, many people may become involved in nefarious activities that endanger the survival of these areas, such as poaching and deforestation.

To minimize the massive impacts of different unexpected crises like COVID-19, it is recommended to encourage and help the indigenous and local communities with diversified sources of income to reduce their total dependence on natural resources such as beekeeping and fish farming and to introduce environmentally and socially friendly methods of agriculture and fishing that will be more productive with very least impacts on the natural environment.

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Resource assessment for mkinga, tanga and pangani mangrove forest reserves

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ABSTRACT

The assessment of Mangrove resources was conducted in Mkinga, Tanga and Pangani mangrove forest reserves to determine the present quantity and quality of the mangrove forest resources as a prerequisite for re-development of the management plans for the three blocks to replace that of 1991 which has become obsolete. Systematic sampling design was employed to lay concentric circular plots along transects that ran perpendicular to coastline and river banks. A total of 122, 104 and 73 plots were established and inventoried for Mkinga, Tanga and Pangani respectively. Standard forest inventory procedures available in literature were applied to take measurements, collected and process data. A total of 2,457, 1.,381 and 1,318 trees were counted, identified by species and measured respectively from 8 mangrove tree species. The results show that the area covered by mangrove forest in Tanga Mangrove Forest reserve accounted to about 9,501 ha in over 40 patches along the shores and river deltas. Mangrove forest spans about 4,813 ha in Mkinga, 1,722 ha in Pangani and 2,966 ha in Tanga Urban. Further, these results demonstrate that the mangrove area has been decreased by 11% with main affected area being Mkinga District with a loss of around 24% of the area reported by Semesi, (1991). These results suggest that the mangrove in the three surveyed blocks are in a good recovery pattern and can self-sustain if appropriate management prescriptions are put in place and adequately enforced. However, there will be no issuance of harvesting permits instead the coastal communities will be enabled to benefit from carbon trade out of sustainable conservation of mangrove and sea grass ecosystems (Climate Champions, 2022, ATIENO S., 2022). The findings serve as baseline information for the development and/or updating of the mangrove forest management plans for Mkinga, Tanga and Pangani blocks.

Keywords: Sample plots, Management plan, Mangrove forests, Resource assessment

INTRODUCTION

Mangrove forests are valuable ecosystems in the tropics and subtropics, occupying around 13.6 million ha worldwide (Spalding and Leal, 2021). On Mainland Tanzania, mangrove forests cover a total area of 158,100 ha (MNRT, 2015, Figure 1), distributed in fragmented and continuous stands of mixed species on gently sloping shores and around river estuaries, creeks and bays along almost the entire coastline. The dominant and well-developed mangrove stands are found at the estuaries of Pangani, Wami, Ruvu, Matandu, Mbwemkuru, Ruvuma and Rufiji (Mangora *et al.*, 2016). For management purposes, Tanzania Forest Service Agency (TFS) has grouped the coastal districts with mangroves into three zones namely, the Northern Mangrove Zone, which include the districts of Mkinga, Tanga and Pangani; the Central Mangrove Zone include the districts of Bagamoyo, Kinondoni, Temeke, Ilala, Kigamboni, Mkuranga, Mafia and Kibiti; and the Southern Mangrove Zone are the districts of Kilwa, Lindi and Mtwara. In the 1991 National Management Plan for Mangrove Ecosystems of Mainland Tanzania (MNRT, 1991; Semesi, 1992, these districts, some of which are new, were designated as management blocks. For Tanga region, Mkinga (formerly Muheza) and Tanga were designated as Block 1, while Pangani was named Block 2. Ten mangrove species are reported to occur in Tanzania (Mangora *et al.*, 2016). These are *Rhizophora mucronata, Ceriops tagal, Bruguiera gymnorhiza, Avicennia marina, Sonneratia alba, Heritiera littoralis, Xylocarpus granatum, Xylocarpus mollucensis, Lumnitzera racemosa and Pemphis acidula*.

Mangroves support both ecological integrity and dependent livelihoods across scales (UNEP, 2014; Spalding and Leal, 2021, Figure 2). Ecological values of mangroves include provision of breeding, feeding and nursery grounds for many species of fish, protection of the coastline from erosion etc. Mangroves are also receiving attention for their role as carbon sink (Donato *et al*., 2011, Pendleton *et al*., 2012, Siikamäki *et al*.,2012, Njana *et al*., 2021) as they are reported to sequester and store carbon at a rate of three to five times that of other vegetation types such as boreal, temperate, or upland tropical forests (Donato *et al*., 2011). In Tanzania common uses of mangroves include provision of wood as poles, timber, and fuel wood for local consumption and trade (Mainoya *et al*., 1986; von Mitzlaff, 1989).

Despite all these benefits, mangroves are still one of most at risk ecosystems on earth threatened by overexploitation of wood resources and conversion to other land uses (Goldberg *et al*., 2020; Spalding and Leal, 2021). Accordingly, a number of calls to action for sustainable management, conservation and restoration to secure the future of mangroves have been made repeatedly (Valiela *et al.*, 2001; van Lavieren *et al.*, 2012; UNEP, 2014; Njana, 2020; Spalding and Leal, 2021). While these calls are made, Tanzania had developed its national Management Plan for the Mangrove Ecosystem of Mainland Tanzania in 1991 (MNRT, 1991; Semesi, 1992) that elaborated how mangroves forests in the country were at risk and devised measures for sustainable management. The impact of the implementation of the management plan has however, not been adequately studied.

With over three decades without revision, the management plan is considered obsolete, given the substantial environmental, soci-economic and governance changes that have occurred. To address this, Tanzania Forest Service (TFS) Agency has recently embarked on the revision of the management plan by blocks (URT., (2002)). So far management plans for Rufiji Delta (now in Kibiti) and Kilwa blocks have been developed and approved (MNRT (TFS)., (2020)). The mangrove resource assessment reported here was conducted between 2018 and 2020 as a prerequisite for revision of the management plans for Mkinga, Tanga and Pangani blocks.

The assessment of Mangrove resources was conducted in Mkinga, Tanga and Pangani mangrove forest reserves to determine the present quantity and quality of the mangrove forest resources as a prerequisite for re-development of the management plans for the three blocks to replace that of 1991 which has become obsolete. The results show that the area covered by mangrove forest in Tanga Mangrove Forest reserve accounted to about 9,501 ha in over 40 patches along the shores and river deltas. Mangrove forest spans about 4,813 ha in Mkinga, 1,722 ha in Pangani and 2,966 ha in Tanga Urban. Further, these results demonstrate that the mangrove area has been decreased by 11% with main affected area being Mkinga District with a loss of around 24% of the area reported by Semesi, (1991).

According to Kairo, (2010), the loss of mangroves coverage in Mkinga district during the last decade is estimated at 20%. The lack of environmental education, which manifests itself in an inadequate understanding of the functions and values of mangrove ecosystems, the conversion of mangrove areas for solar salt pans, the use of mangrove wood for boiling water for salt production, firewood, and charcoal making, the illegal harvesting of wood for export into the neighboring country, and unsustainable agricultural practices are some of the underlying root causes of mangrove degradation in the Mkinga District (Kairo, 2010).

MATERIALS AND METHODS

Study area

Tanga Region is the northernmost part of the coastal mainland Tanzania with a total area of 26,808 km^2 (Wells *et al*., 2007, Figure 1). Mkinga District is the Northern most district of the region while Tanga stride in the middle, while Pangani District in the south of the region (Figure 2). Mangrove forests covers about 9,501 ha, shared in the three blocks as follows: Mkinga block (4,813 ha), Tanga block (2,966 ha) and Pangani block (1,722 ha, Figure 2).

About 60,947 people inhabited villages located adjacent to the mangrove forest reserves. Majority of the population in close proximity to the mangrove ecosystems in the region rely mostly on agriculture, livestock keeping, forestry and fishing as well as petty trade. Harvesting of mangrove poles is one of the important economic activities for income generation (URT, 2018). Mangroves are also a local source of firewood, charcoal, building poles, construction materials, boat building, fish traps, fishing stakes and traditional medicines (Samoilys *et al*, 2008, Muhando, 2011; Mangora and Shalli, 2012).

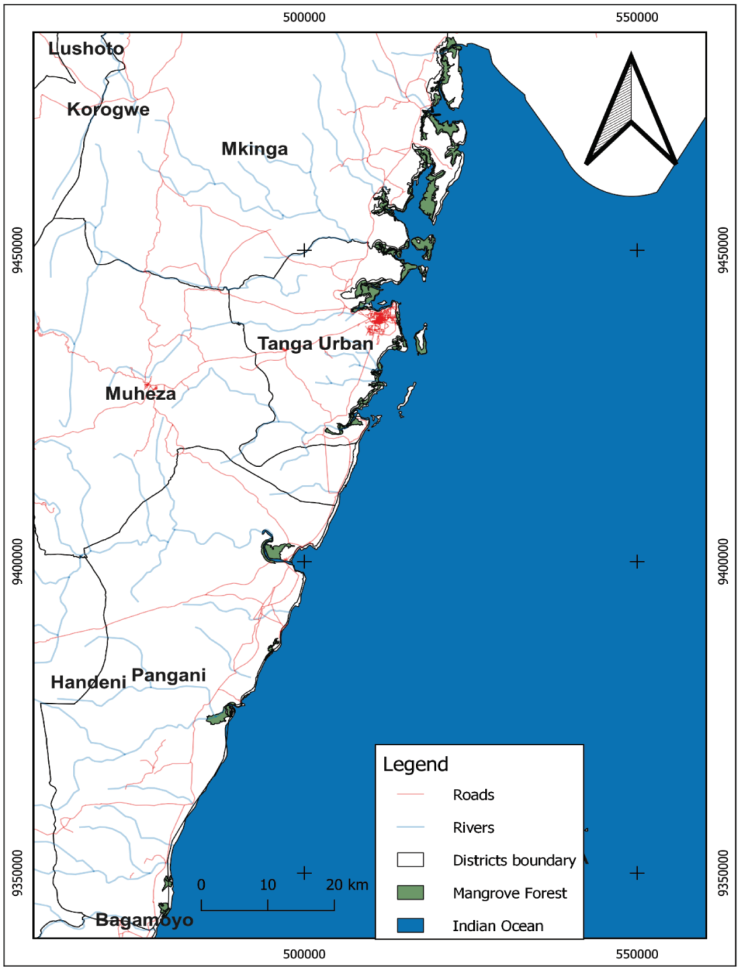

Figure 2. Map of Tanga region mangrove forest reserve showing location, District boundaries as well as marine and coastal resources

Survey mangrove stands

The mangrove resource assessment reported here was conducted between October to November 2018 and February and March 2020 as a prerequisite for revision of the management plans for Mkinga, Tanga and Pangani blocks. Mangrove areas identified for inventoring in Mkinga District include those at the border between Tanzania and Kenya (Jimbo village in Kenya and Jasini village in Tanzania) Mahandakini, Kijiru, Moa, Boma Subutuni and Boma Kichakamiba villages, Kwale island and Kwale, Mongavyeru, Kichalikani and Kizingani villages. Tanga district included the mangrove areas of Bwagamoyo, Chongoleani, Putini, Mvuuni, Mafuriko, Kisosora, Sahare, Kwamakofia, Donge, Mwarongo wa Digo, Machui, Neema, Mchukuuni, Tongoni, Kirare and Mwarongo streets, small islands of Ulenge, Toten, Jambe and Karange. Pangani district included the mangroves areas of Pangani magharibi village, Pangani river banks, Ushongo, Kipumbwi, Sange, Mkwaja and Buyuni villages.

Sampling design

A total of 122, 104 and 73 plots were inventoried in Mkinga, Tanga and Pangani respectively; and from each area a total of 7 species (2457 trees), 6 species (1381 trees) and 8 species (1318 trees) respectively were recorded. Concentric circular plots were used to capture information at different diameter classes. Systematic sampling design was employed, such that sampling plot locations for each site mentioned in section 2.2 above were determined by running computer QGIS programme to produce systematic coordinate points which were then recorded on a booklet and uploaded into GPS receiver, to assist accessing points in the field. Sampling plots were systematically laid along transects established perpendicular to the shorelines or river bank where each plot was comprised of four circular fixed-area concentric sub plots of 2-m, 5-m,10-m and 15-m radius for inner, middle 1, middle 2 and outer circles respectively to capture information for different tree diameter classes as shown in figure 3. This plot type was used for easy of establishment on the ground. The inter plot distance was 500-m.

Plot measurements

In each sampling plot, the following parameters were collected and recorded in the inventory form: plot number, tree number, stem number (for trees with multiple stems), species name, diameter at breast height (DBH) and remarks like number of seedlings, saplings, dead logs. For DBH measurements, which was done using a forest calliper, the following protocol was observed: all trees with DBH ≥1, ≥5, ≥10, ≥15 cm was identified by species and measured their DBH (cm) for radii 2, 5, 10 and 15 m respectively. For *R. mucronata* trees, stem diameter was taken at 30 cm above the highest prop root, while for the dwarf plants diameters were measured as down as possible.

Disturbances observed include forest clear felling for economic gain, urban development, beach hotel development, agriculture (salt ponds), aquaculture (fish ponds) in Jasini, Mahandakini, Kijiru, Moa, Mwaboza, Vuo, Boma Subutuni and Boma Kichakamiba villages (Boma Peninsula and Manza bay), Kwale island and Kwale, Mongavyeru, Kichalikani and Kizingani (Mkinga district); Bwagamoyo, Chongoleani,

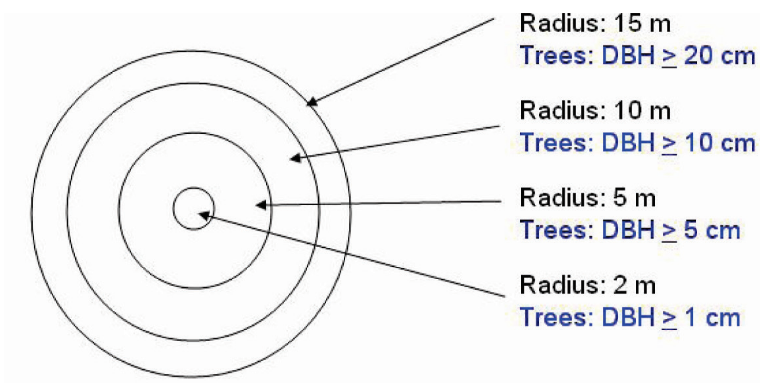

Figure 3. Concentric sample plot

Putini, Mvuuni, Mafuriko, Kisosora chumvini, Sahare, Kwamakofia, Donge, Mwarongo wa Digo, Machui, Neema, Mchukuuni, Tongoni, Kirare and Mwarongo streets, small islands of Ulenge, Toten, Jambe (Tanga district) and Pangani magharibi village, Pangani river banks (Pangani estuary), Ushongo, Kipumbwi, Sange, Mkwaja and Buyuni villages in Pangani district. The disturbances were recorded using prepared data collection sheets provided during the inventory exercise. The crue teams have always been accompanied by relevant village leaders just to make sure that the community members are fully involved in the inventory exercise.

Data processing and analysis

Forest density, basal area and volume

Using standard forest inventory data processing procedures, tree density (N), basal area (G) and tree volume (V) were calculated and summed up for each sample plot and subsequently up-scaled to per hectare estimates (N (trees ha^{-1}), G (m^2ha^{-1}) and V(m^3ha^{-1}).

Harvestable volume was calculated using allometric equation available in literature:

$$v = 0.000202(dbh)^{2.361854)}$$

Species Importance

Important Value Index (IVI) was calculated as the sum of Relative Frequency (RF), Relative Density (RD), and Relative Dominance (RDo) of species, calculated as indicated in the formula below. This index is useful in evaluating the importance of a given species in a given plant community (Kent and Coker, 1992) and key in the description of forest structure. The maximum value of IVI is 300.

Statistical analysis

Microsoft excel and R statistical programme was used to do calculation and produce summary statistics comparing means of different structural parameters (DBH distribution, basal area, volume) and generate display tables and graphs.

RESULTS

Forest composition and structure

A total of 122, 104 and 73 plots were inventoried in Mkinga, Tanga and Pangani respectively; and from each area a total of 7 species (2457 trees), 6 species (1381 trees) and 8 species (1318 trees) were respectively were recorded. Those 8 mangrove tree species were identified as *Avicennia marina* (Acanthaceae), *Bruguiera gymnorhiza* (Rhizophoraceae), *Ceriops tagal* (Rhizophoraceae), *Heritiera littoralis* (Malvaceae), *Lumnitzera racemosa* (Combretaceae), *Rhizophora mucronata* (Rhizophoraceae), *Sonneratia alba* (Lythraceae), and *Xylocarpus granatum* (Meliaceae) (Table 1). Although not found in the sampling plots, *X. moluccensis* has also been observed in some mangrove stands of Tanga and Pangani (Mangora, per. observation). Non mangrove species were also recorded including *Manilkala spp*, *Mcheji maziwa spp*, Sterculia *spp* and *Mswaki spp*.

Table 1. Eight mangrove species recorded in the Mkinga, Tanga and Pangani mangrove forest areas and their local uses

Species	**Family**	**Uses**	**Local name**
Ceriops tagal (Perr)	Rhizophoraceae	Poles, Sawing, Firewood	Mkandaa
Bruguiera gymnorrhiza (L.) Lam	Rhizophoraceae	Poles, Sawing, Firewood	Mshizi
Rhizophira mucronata Lam	Rhizophoraceae	Poles, Sawing, Firewood	Mkoko
Sonneratia alba (Sm)	Sonneratiaceae	Poles, Sawing, Firewood Boat making	Mpira
Avicennia marina (Forsks.) Vierh	Acanthaceae	Inferior firewood	Mchu
Lumnitzera racemose (Will)	Combretaceae	firewood	Mkandaa dume
Xylocarpus granatum (Koen)	Meliaceae	Poles, Sawing, Firewood	Mkomafi
Heritiera littoralis (Dryand)	Sterculiaceae	Poles, Sawing, Firewood	Mkungu

Diameter distribution

Majority of tree stems recorded were with dbh of below 0-05 cm (figure 4).

Forest density for Mkinga mangrove block was 1,982±408 while that of Tanga block was 4,310±737 and Pangani block was 2,746±756 (Table 2). Mean basal area per ha for Mkinga block was 13.32±2.42 m^2, for Tanga block was 9.589±1.46 m^2 and for Pangani block was 13.22±2.18 m^2 (Table 2).

Mean volume per ha for Mkinga block was 72.68±9.76 $m^3$and total volume for the whole forest 460,719.56±62005.28 m^3. For Tanga block, mean volume per ha was 53.45±9.58 m^3 and volume for the whole forest was 163,022.5±29.219 m^3. For Pangani block, the mean volume per ha was 86.0±14.36 m^3 and volume for the whole forest was 151,016±25,268.84 m^3 (Table 2).

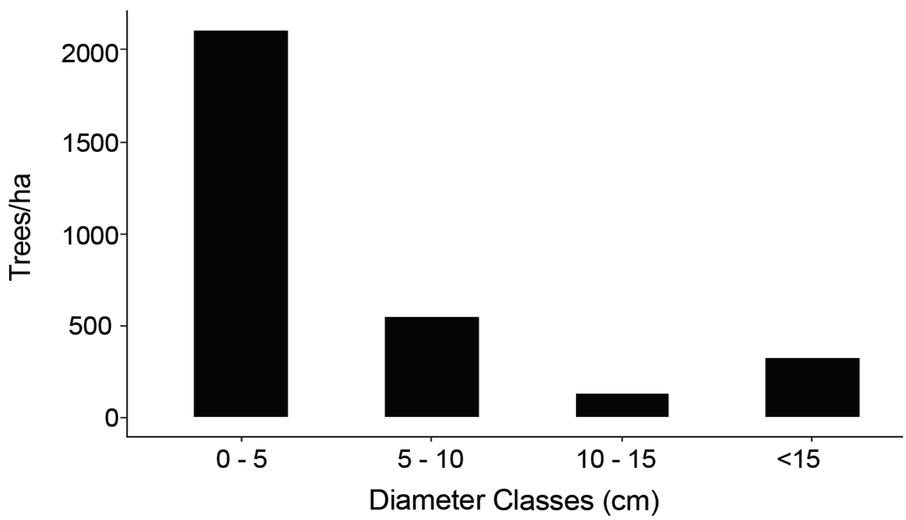

Figure 4. Number of trees per hectare distributed per diameter class for Mkinga, Tanga and Pangani blocks.

Table 2. Forest density, basal area and tree volume by species in Mkinga, Tanga and Pangani mangrove blocks

District	Species	Average density (stems ha^{-1})	Average basal area (m^{2}ha^{-1})	Average volume (m^{3}ha^{-1})
Mkinga	*Avicennia marina*	114.0755375	0.86493577	5.34
	Bruguiera gymnorhiza	68.24239272	0.70338524	4.24
	Ceriops tagal	458.3024582	1.47699399	7.01
	Lumnitzera racemosa	8.98689114	0.03377613	
	Manilkala spp	0.260909743	0.00819257	0.11
	Mcheji maziwa	3.391826656	0.01413218	0.02
	Mswaki (Sw)	0.637779371	0.01541113	0.06
	No trees	1.4205086	0.01259835	0.12
	Rhizophora Mucronata	1084.224931	7.65870893	41.31
	Sonneratia alba	236.8190765	2.42951161	13.76
	Sterculia spp	0.231919771	0.02080001	0.3
	Xylocarpus granatum	5.276174798	0.07917626	0.41
Total		1,981.87	13.31762217	72.68
Tanga	*Avicennia marina*	1023.285	2.581	15.517
	Bruguiera gymnorhiza	182.11	0.415	2.158
	Ceriops tagal	1297.079	1.616	8.233
	Lumnitzera racemosa	1.224	0.003	0.017
	No trees	0	0	0.000
	Rhizophora mucronata	1465.314	3.752	20.256
	Sonneratia alba	340.687	1.222	7.273
Total		4309.698	9.589	53.453
Pangani	*Avicennia marina*	600.961	3.722	26.364
	Bruguiera gymnorhiza	92.828	0.408	2.438
	Ceriops tagal	1058.998	2.353	12.343
	Heritiera littoralis	6.541	0.089	0.604
	Lumnitzera racemosa	0.436	0.005	0.031
	Rhizophora mucronata	479.936	2.332	13.857
	Sonneratia alba	132.75	1.223	8.417
	Xylocarpus grantum	373.493	3.09	21.946
Total		2745.944	13.223	86.000

Species Importance Value Index (IVI)

Rhizophora mucronata was the top species with the highest IVI in Mkinga and Pangani blocks. On the other hand, *A. marina* and *C. tagal* had the highest IVI for Tanga and Pangani blocks forest while *X. granatum* had exceptionally high IVI in Pangani block. *L. racemosa* (in both Tanga and Pangani blocks) *and H. littoralis* (only in Pangani block) had the lowest IVI (Table 4).

Table 4. Distribution of Importane Value Index (IVI) for Mkinga, Tanga and Pangani mangrove forests

District	Species	RF (%)	RDe(%)	RDo(%)	IVI (%)
Mkinga	*Rhizophora mucronata*	63	55	58	176
	Avicennia marina	8	6	7	21
	Ceriops tagal	15	23	11	49
	Sonneratia alba	8	12	18	39
	Bruguiera gymnorhiza	5	4	5	13
	Xylocarpus granatum	1	0	1	2
	Lumnitzera racemosa	0	0	0	0
	Overall	100	100	100	300
Tanga	*Rhizophora mucronata*	39	34	39	112
	Avicennia marina	26	24	27	77
	Ceriops tagal	16	30	17	63
	Sonneratia alba	14	8	13	35
	Bruguiera gymnorhiza	5	4	4	13
	Overall	100	100	100	300
Pangani	*Rhizophora mucronata*	19	17	18	54
	Avicennia marina	27	22	28	77
	Ceriops tagal	18	39	18	75
	Sonneratia alba	10	5	9	24
	Bruguiera gymnorhiza	3	3	3	9
	Xylocarpus granatum	23	14	23	60
	Lumnitzera racemosa	0	0	0	0
	Heritiera littoralis	0	0	1	1
	Overall	100	100	100	300

Note: RF: Relative frequency, RDe-Relative density, RDo-Relative dominancy and IVI-Importance value index

DISCUSSION

Our results show that the mangrove forests are growing and developing apart from being faced by high level of illegal harvesting. Such information on forest structure, relationships between structural parameters are important in ensuring the sustainability of mangroves and the associated ecosystem services through sustainable management planning for various management operations and enforcement. There is low mangrove species diversity in eastern Africa region when compared to the most diverse mangrove species region of South east Asia where over 40 species occur (FAO, 2007; Hinrichs *et al*., 2009; Nandy and Kushwaha, 2010; Chowdhury et al., 2016). The eight mangrove species recorded in Mkinga, Tanga and Pangani, have been reported previously in other East African countries (FAO, 2007; Njana *et al*., 2018).

The structural parameters for mangrove forests in Mkinga, Tanga and Pangani are comparable with the reported results for mangroves in other East African countries, whic h have similar climatic conditions. For example, Tamooh *et al*. (2008) reported tree density (N) of 3067-3567 trees ha^{-1} and basal area (G) of 15.9-17.0 $m^2 ha^{-1}$ for the mangroves of Gazi Bay in Kenya and Trettin *et al*. (2016) reported N of 2000 and G of 14-41 m^2 ha^{-1} from the Zambezi Delta in Mozambique. Similarly, *R. mucronata* has been reported to be the most important species in many stands across the region, reported to be the most dominant in all the major mangrove countries of the region (Bosire *et al*., 2016).

The presence of many trees of diameter class 0-5 for the 3 mangrove blocks of Mkinga, Tanga and Pangani shows that the forests are growing apart from being faced by high level of illegal harvesting (figure 4). This is supported by the observed values of high mangrove forest density, particularly for Tanga block with over 4,000 stems ha^{-1} and the average density of over 2,000 stems $ha^{-1.}$ This is characteristic to naturally recovering forests that exhibit many trees of small diameter and few trees of large diameter. Based on the diameter class distribution provided by the forest regulations for harvesting purposes (Table 5), and the fact that the average trees per hectare for diameter class III and IV were generally greater than that of class I and II (figure 4), further explain the overall ability of the surveyed forest to self-sustain if management prescriptions are adequately enforced. The pole size of diameter class II and IV are also the most demanded for common local and commercial uses, particular for traditional house construction. While large trees of diameter 35-40cm and above (especially *Xylocarpus granatum*) are preferred for timber and therefore most targeted for pit sawing. Unlike in other areas, Pangani Estuary mangroves had most of large *X. granatum* tree intact, which may possibly be linked to high level of security in the area which is close to Pangani town.

Table 5. Number of classes according to market demand

No	Class category	Diameter class in cm
1	I	15 – 20
2	II	10 – 14.9
3	III	5 – 9.9
4	IV	Less than 5

Occurrence of many of the mangrove stands in the three blocks in the settings of lagoon mangroves formed in and around semi-enclosed bodies of water that receive seasonal freshwater delivery support ecological integrity. This natural orientation of the mangroves of these blocks supported by a number of small river estuaries like those of Ngole, Zigi, Kirare Mkinga and Tanga, and Kipumbwi-Sange in Pangani, is supposedly coupled by the governance push through the excellent conservation measures done by the Mangrove Management Project (1994/95 to 2005/2006) that to a large extent addressed the indiscriminate cutting of mangrove trees for salt making (boiling of brine water and solar salt evaporation pans) and other unsustainable and environmentally unfriendly uses.

Even though the total mangrove area for Mkinga is about 4 times that of Pangani, the basal area for Mkinga block mangroves is far less than that of Pangani. Luxurious growth of *Xylocarpus granatum* 3.09 $m^2\ ha^{-1}$ and *Avicennia marina* 3.72 m^2ha^{-1} along Pangani river banks has significantly contributed in the high value of overall basal area (13.32 $m^2\ ha^{-1}$). This is associated to the fact that Pangani mangroves are riverine, similar to those of the Rufiji Delta that favours well developed mangroves due to ecological balancing of sediment accretion and freshwater supply (Mitzlaff, 1991). This is reflected in the largest volume of 86.0 $m^3\ ha^{-1}$ observed in Pangani block, largely contributed by luxurious growth of *Avicennia marina* (26.36 $m^3\ ha^{-1}$) and *Xylocarpus granatum* (21.95 $m^3\ ha^{-1}$) in the Pangani Estuary. The results presented here are generally comparable to those reported from Rufiji Delta, which is reported to have a growing stock of 4727 stems ha^{-1}, basal area of $18.12 \pm 1.45\ m^2ha^{-1}$ and volume of $140.09 \pm 14.54\ m^3ha^{-1}$ (URT, 2020) and Kilwa block wich is reported to have a growing stock of 7,738 ± 305 stems ha^{-1}, basal area 14.23 ± 0.3 m^2ha^{-1} and volume of 79.96 ± 0.79 m^3ha^{-1} (URT 2019).

CONCLUSION

The findings of this resource assessment suggest that the mangrove forests in the three surveyed blocks are in a good recovering pattern and can self sustain if appropriate management prescriptions are put in place and adequately enforced. High density of trees of diameter class 0-5 (poles class IV) may support issuance of harvesting permits for only class IV poles with strict control measures, including development of local harvesting plan that defines the actual allowable cut under selective cutting and rotation cycles (figure 4). However, at present Mkinga district is implementing an initiative "Tanzania and Kenya Transboundary Marine Conservation Area (TBCA)". One of the outputs of the initiative is to enable the coastal communities benefit from carbon trade out of sustainable conservation of mangrove and sea grass ecosystems (Climate Champions, 2022, ATIENO S., 2022). This issue entails total conservation of mangroves not only in Mkinga district but also in Tanga and Pangani mangrove areas because there are also prospecting for implementing the same carbon projects in the remaining districts. In addition, harvesting should not be conducted in Tanga and Pangani blocks because research findings show that mangrove forest density for the Tanga block is characteristic to naturally recovering forests following persistent illegal harvesting and that Pangani block continue to have the lowest mangrove area coverage with the highest concentration and luxurious growth of mangroves being protective mangroves along Pangani and Msangazi river banks. There are also a number of threats facing mangroves of these areas including oil and heavy metal pollution, pests and diseases, excessive siltation as well as natural threats.

Since the overall forest management for the three blocks has for years been based on outdated and unreliable data and information due to inadequate collection, analysis, interpretation, dissemination, storage and updating of forest resource information as well as inadequate application of indigenous knowledge in mangrove forest resources management, the findings from the present resource assessment will help to develop and update mangrove forest management plans in mangrove areas of Mkinga, Tanga and Pangani blocks.

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Assessment of behavioral responses of elephants on drone deployment in Mkomazi National Park, Northern Tanzania

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ABSTRACT

The study was conducted at Mkomazi National Park in Northern Tanzania on June 2021. Thestudy aimed to assess the behavioral responses of elephants on deployment of drone. Since elephants are the main sources of human elephant conflicts, there is a need to devise mitigation methods that are safe, efficient and accurate, but yet not overly painful for the elephants. Drones are gradually more being used recreationally, commercially and for wildlife research, but very few studies have quantified the behavioral responses of elephants to drone deployment. This study demonstrated drone application as a potential tool for mitigating human – elephant conflict, using this technology to observe behavioral responses of elephants. Field work was conducted using the DJI Mavic air 2 drone, where drone was flown at constant height and varied horizontal distances towards individual or groups of elephants. Elephants responded by displaying different behaviors such as ear flipping, trumpeting, charging, running and still standing. The Generalized Linear Model and Pearson-chi square was used to test the differences in behavioral responses to drone deployment. It was shown that deployment of drones was effective in eliciting running to elephant individual or in groups at distances of up to 200m, and that longer running distances were correlated with closer approaches of drone. Age and sex differences had no apparent effects on the behavioral responses. It is concluded that use of drones can be a useful tool for mitigating human elephant conflicts.

Keywords: Behavioral responses, drone deployment, elephants, human elephant conflicts

INTRODUCTION

Elephants are the largest living land animals, which are characterized by their extended trunks (Lengthened upper lips and nose), columnar legs, and huge heads with temporal glands and wide, flat ears. Elephants are grayish to brown in color, and their body hair is sparse and coarse. They are considered as ecosystem engineers and umbrella species due to their acts of modifying their habitats by rearranging successions of forested habitats to grassland, digging holes to access water in time of droughts and spreading the propagules of numerous plant species. They are mostly found in savannas, grasslands, and forests but occupy a wide range of habitats, including deserts, swampand highlands in tropical and subtropical regions of Africa and Asia. There are two genera of living elephants (order proboscides, family Elephantidae), which are Asian elephant (Elephas) and the African elephant (Loxodonta) (Sukumar, 2003).

The sub-Saharan region of Africa is estimated to have 500,000 elephants, in 37 range countries. African elephants consist of forest and savanna subspecies, which are both endangered. African savanna elephants are categorized by IUCN red list of threatened species as critically endangered while African forest elephants are categorized as endangered. This is due to severe poaching and habitat loss.

Human elephant interaction is the one of the foremost challenges facing the management of protected areas in both Africa and Asia (Mace et al., 2018). This is due to increased human population which has escalated the interaction between elephants and people, particularly in areas adjacent protected areas (Acharya et al., 2011). Many incidents of human kills and crop damage by elephants have taken place in Tanzania and in many other countries.

There are several mitigation strategies that have been applied to minimize the negative impacts caused by elephants. They include fencing, which has been associated with potential negative effects on wildlife such as blocking of migratory routes (Sutherland et al., 2017). Use of chilies

(Osborn & Parker, 2002) and use of bees (Cook et al., 2018) are alternative approaches for deterring elephants. Recently, drones appear to offer a flexible, accurate and affordable solution to some of the technical challenges in conservation of natural resources (Chabot & Bird 2015; Linchant et al.,2013). Different studies have shown that deployment of drones are useful in a variety of wildlife management situations such as population surveys (Chabot & Bird 2015), wildfires tracking (Jones et al 2006) and elephant population and ecological monitoring, respectively (Lejeune et al., 2013): Mangewa et al., 2019) and in anti-poaching efforts (Mulero-Pázmány et al., 2014). In part, this because drones have increasingly become widely available and affordable. This study aims to explore the behavioral responses of elephants on drone stimuli as a proxy for mitigating human elephant conflicts.

Crop damage by elephants is the most prevalent form of Human elephant conflicts (Davies et al., 2011). Such damage affects the rural farmer's livelihood and deepens poverty.

There is therefore a need to devise mitigation methods that are safe, efficient and accurate, but yet not overly painful for the elephants. Currently, provision of conservation education to local communities and physical deterrence of elephants with vehicles and guns are the main techniques in Tanzania. However, these have limited success, as they are costly and time consuming. This failure has led to an escalation of human elephant conflicts. Deployment of drones could provide an alternative solution to the problem.

Drones are a promising conservation tool in many aspects, including elephant human conflict mitigation. Few studies have focused on drone deployment to assess behavioral responses of elephants see e.g. (Bennitt et al. 2019: De 2021). These studies show that elephants variably respond to drone deployment. Such initial indications call for further testing especially in rural areas overwhelmed by human elephant conflicts as part of the human-elephant conflict mitigation measures for wildlife managers and communities dealing with high levels of conflicts with wildlife.

The main objective of this study was to assess the contribution of drones as a potential tool for mitigating human elephant conflicts with three specific objectives which were to i) assess the age dependent behavioral responses of elephants to field deployment of drone; determine the sex specific behavioral responses of elephants towards field deployment of drone and determine the behavioral response of group elephants to field deployment of drone.

MATERIALS AND METHODS

Study area

The study was conducted in Mkomazi National Park, which is located in northeastern in Tanzania and it is contiguous with Kenya's Tsavo West National Park. It covers about 3500 kilometers

square, and is a unique protected area in Tanzania with large and visible populations of the rare Gerenuk and Beisa Oryx. It is dominated by *Acacia commiphora* vegetation. The Park has a semi- arid climate with a bimodal rainfall distribution pattern, and is one of the richest savannahs in Africa in terms of rare and endemic flora and fauna, evidenced by the presence of wild dogs and black rhinos. The Park was established in 1951 as a Game Reserve and upgraded to a National Park in 2006.

Drone specifications and operating procedures

A DJI Mavic air 2 (DJI, China), drone was used to collect data with technical specifications shown in **Table 1**. Survey was done for 2 days in areas overwhelmed by human elephants conflicts. The drone was flown horizontally at 5 m per second (m/s) directly towards the located elephants at predetermined distance intervals (<10 meters, 10<40 m, 50<90 m and >90 meters). At all distance behavioral responses were observed and recorded in a standard data sheet. All flights were conducted using the DJI Go 4 flight app, and all recordings were occurred between a height range of 10-15m (in open

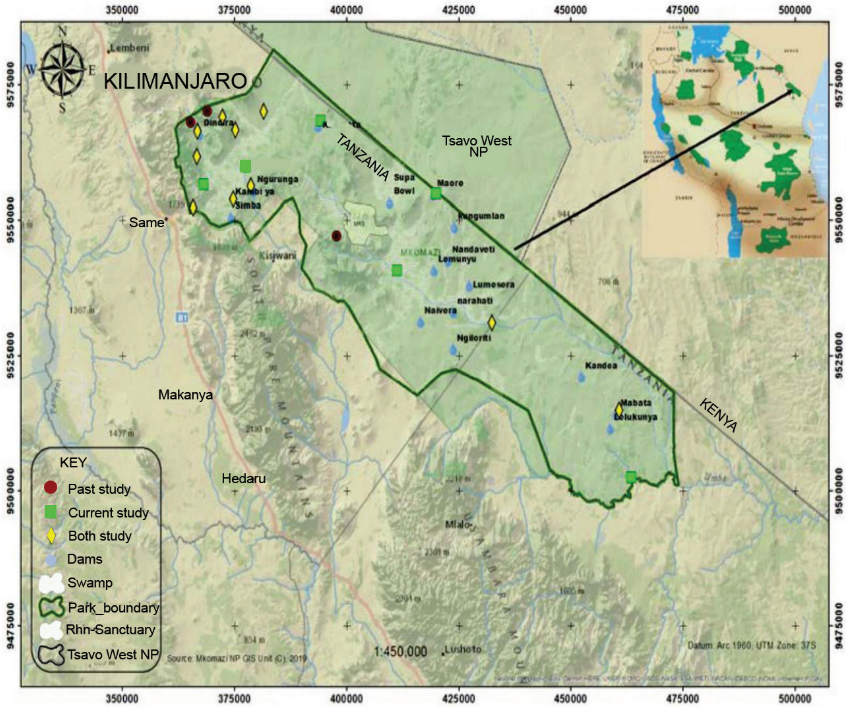

Figure 1. Study area, Mkomazi National Park

grassland and open woodland) and 75-90m (in forest area). The equipment requires no rigorous previous operating experience with remotely controlled drones. Basic flying can be learned within a few hours of practicing (Lorah et al.2018). Operators had three (3) years of basic experiences in flying drones. Prior to actual data collection, three trials were attempted in order to calibrate the equipment. No consistent drone flights have been tested at Mkomazi National Park prior to this study; so that the behavioral responses of the elephants to the drone were not biased by previous experiences.

Study design and sampling procedure

Purposive sampling was used (Fig.2) based on reported/encountered elephant cases during patrols. When elephants were encountered, distance from vehicle were estimated (in meters) by using rangefinder (Bushnell ®, Laser range finder), their numbers and age-sex structure (juvenile, young and adults) recorded. When the elephants were in groups, distances from the centre of the group to the respective reference point of the vehicle were estimated. Thereafter, a drone hovered on the groups or individual elephants in a standardized way. Sampling frequency depended on sightability but attempts were made to survey at least 10 elephants groups. For individual behavioural responses; when an elephant was encountered, its age, sex and the distances from vehicle or patrol group were also recorded, followed by drone flying in a similar manner to that of the group.

Table 1. Drone specifications

Item description	Technical specifications
Types of drone	Four rotored helicopter
Image resolution	12 Megapixel
Video resolution	2K
Maximum flight time (no wind)	21 Minutes
Maximum hovering time (no wind)	20 Minutes
Maximum flight distances (no wind)	10 kilometers
Operating temperature	0-40 centigrade
Control operating frequency	2.400- 2.4835 GHz
Maximum ascent speed	4m/s (S- Mode), 2m/s (P- Mode) and 2m/s (Wi-Fi mode**)**
Maximum descent speed	3m/s (S- Mode), 1.5m/s (P- Mode) and1m/s (WiFi mode)
GNSS	GLONASS +GPS
Maximum wind resistance	29-38 Kph
Video transmission system app	DJI GO 4
Battery	2970mAh
Take-off weight	430g

Data collection

Behavioral sampling

Behavioral responses to drone deployment were observed directly. This research primarily focused on reducing human-elephant conflicts by repelling individual elephants from potential farm areas.

Therefore, their movement patterns or other behavioral response following deployment of drones were carefully observed. Primary interest was whether they will flee (and at what distance) or remain still. Other expected behavioral responses include ignoring the drone, feeding, making noise, and charging toward the vehicle or patrol group. These and any other behavioral responses following drone deployment were directly recorded in the field. The estimated distance from vehicles to elephants, age and sex structure of elephants, number of elephants, estimated fleeing distances and other behavioral reactions of elephant were

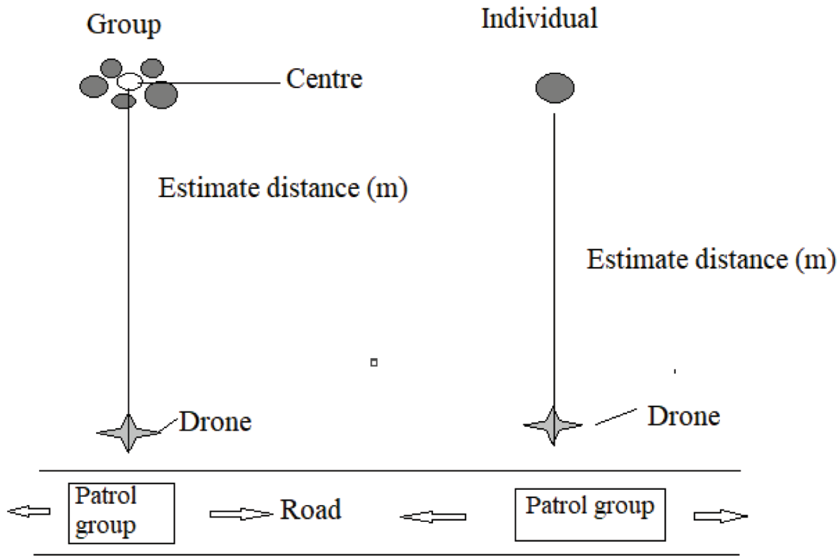

Figure 2. Sampling design for elephants individual and groups

all recorded. Distance from individuals or group of elephants to the patrol vehicle was directly measured in meters using a range finder, and was taken as an independent factor, while behavioral responses were taken as dependent variables. Detailed notes and observations were made associated with each drone flight; information was collected on date, time, behavioral responses, coordinates, estimate distances from vehicle to elephants, running distances, flight duration, type of habitats, drone height, distances from elephants to drone and remarks. All these data were recorded on a standard data sheet.

Data analysis

Data collected from the field were entered in Microsoft Excel datasheets. Statistical analyses were undertaken in the R environment and SPSS software Version 20. Statistical analyses employed Generalized Linear Model (GLM) in the R environment and chi- square using SPSS software Version 20. Analyses were carried out to explore behavioral differences displayed by individual or group elephants in response to drone deployment distance. Chi-square test (x^2) was used to test the differences in frequency of individual or group elephants behaviors, while the Generalized Linear Model was used to determine the correlation of elephant running distances and drone approach.

RESULTS

Distribution of individual elephants

A total of seven individual elephants were assessed in the field of which 6 elephants were outside the park and 1 elephant within the park (Fig. 3).

Distribution of elephant group

A total number of 10 elephant groups were assessed in the field where by 3 groups were within the park and the rest were outside the park (Fig. 4).

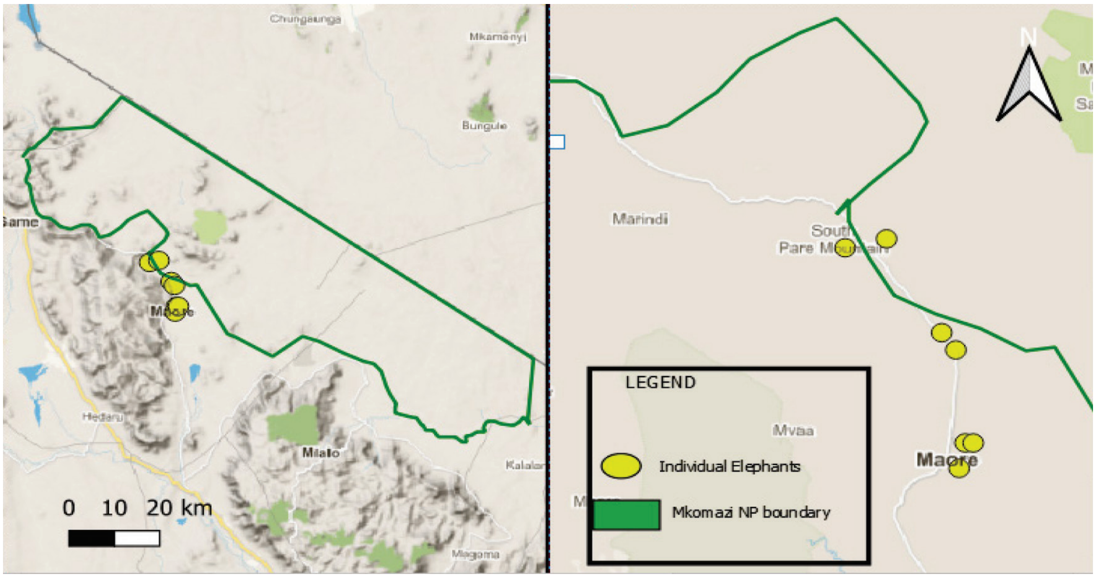

Figure 3. Sightings of the sampled individual elephants.

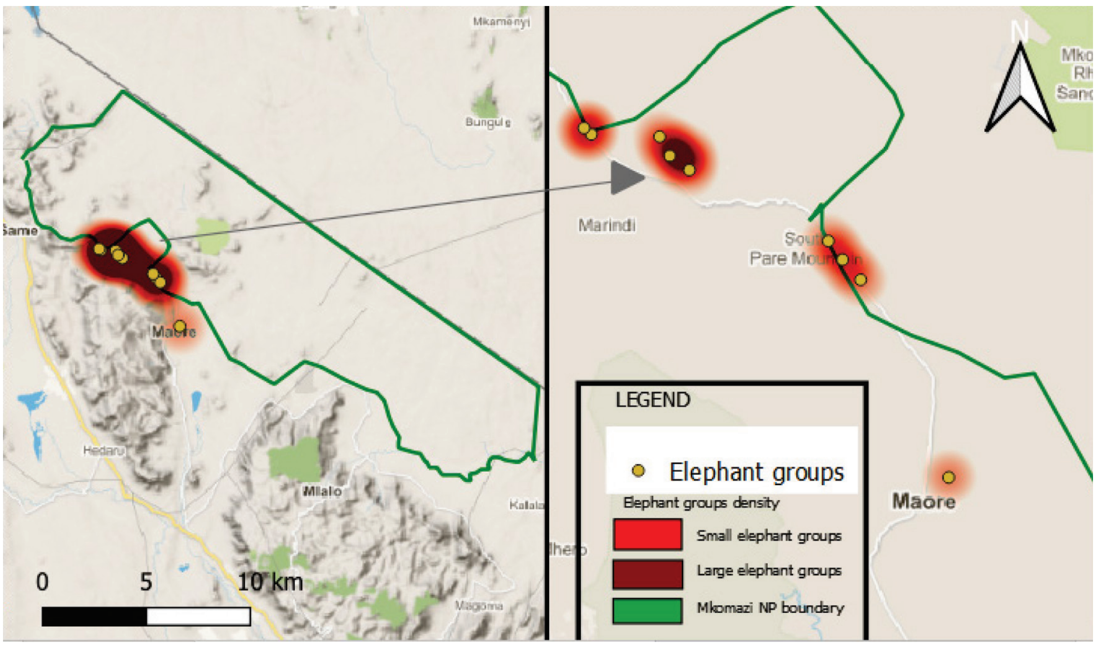

Figure 4. Sightings of sampled group of elephants

Behavioral responses of individual elephants

Age-related responses

A total number of seven individual elephants were assessed in the field composing of five adults and two juveniles. About 2 and 1/2 as much as adults reacted to deployment of drone. However, there were no age specific significant differences related to behavioral responses (n=28; X^2= 3.50; p= 0.62; n.s.). This implies that the age of individual elephants did not account for behavioral differences in responding to drone deployment.

Sex-related responses

A total of seven individual elephants composing of six males and one female were observed. About 85.6% of all displayed behaviors comprised of running, aggression and still standing as summarized in the **Table 2** below. There were no significant sex specific differences in terms of these behavioral responses (n=28; X^2= 3.5; p= 0.62; n.s.) this entails that the sex of elephant was not a reason for them to react differently in response to drone deployment.

Table2. Sex specific behavioral responses of individual elephants (Figure are in %)

Behavioral responses	Sex		Total
	Male	Female	
Still standing	83.3	16.7	100
Trumpeting	100	0	100
Aggressive	66.7	33.3	100
Running	83.3	16.7	100
Ear flipping	100	0%	100
Walking	100	0	100

Sex-specific related fleeing

There was no sex related significant differences related to fleeing distance (n=28; X^2= 6.62; p= 0.36; n.s.) This implies that the sex of individual elephants was also not a reason for them not to flee in response to drone deployment.

Drone approach related to fleeing distance of individual elephants

Drone approach were correlated to fleeing distances of individual elephants, significant difference emerged (n=6; X^2= 6. p= 0.01; **Fig 5**). This implies that fleeing of individual elephants were stimulated by drone approach. The more the drone approached the elephants, the further they run away. For instance, when the drone was hovering on elephants, it ran 200m while when the drone it was 20 m from the elephants it ran about 60m only.

Behavioral responses by elephants group

Elephant groups related

Ten groups were recorded from three habitats (open woodland, open grassland and forest area) at different distances and at different drone height according to the nature of habitat this was to ensure the safety of drone. About 80% of all displayed behaviors within groups comprised of running, aggression and still standing as has been summarized in the **Table 3** below. There were no significant differences between drone approaching distances and behavioral displays of elephant group (n=40; X^2= 195.7; p= 0.2; n.s.) this implies that elephant groups were differently responding to the drone depending on how far the drone was.

Table 3. Behavioral responses of elephants group

Behavioral responses	Frequency	%
Still standing	8	20
Ear flipping	11	27.5
Running	9	22.5
Aggressive	4	10
Trumpeting	7	17.5
Walking	1	2.5
Total	40	100

Drone approach related to fleeing distances of elephants group

A total number of 10 elephants group were assessed in the field. About 90% of elephants group responded to fleeing and the remaining percent elephant group was not responded to running when the drone was flown to them. There were no significant differences between drone approach and fleeing distances (n=10; SE= 1.96; p= 0.22; n.s. R^2 Linear 1.096E^{-4}) this implies that there was no relationship between drone approach and fleeing distances but it seems like there is little relationship because fleeing of elephants were stimulated by drone approach when the drone was coming closer to them (see **Fig 6** below**).**

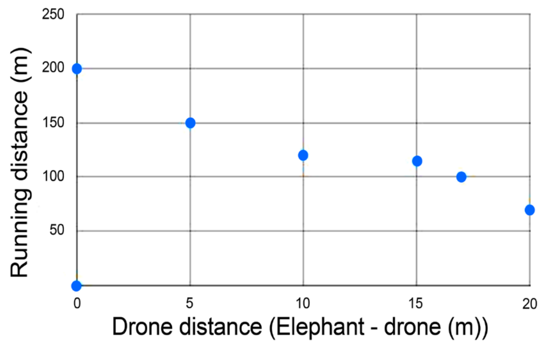

Figure 5. Relationship between drone approach and elephant fleeing distance

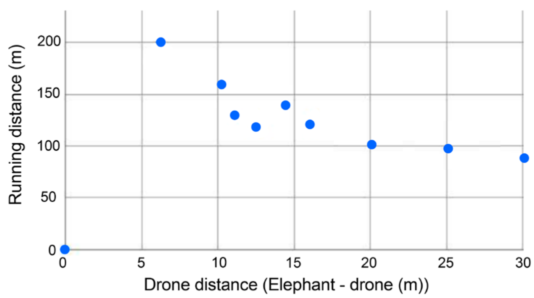

Figure 6. Drone approach related to fleeing distance

Magnitude of fleeing by elephants in response to drone deployment

The sample size of 10 elephant groups and 7 individual elephants were assessed; generally, it shows that the magnitude of fleeing by elephant group was 85.51meters and 90 meters by individual elephants.

Table 4. Fleeing distances (m) by elephants in response to drone deployment

Elephants	Max	Mean	SD
Individuals	200	90	26.91
Group	200	85.51	27.30
Combined	200	87.67	26.31

DISCUSSION

The results obtained at Mkomazi National Park aimed to assess the behavioral responses of elephants on drone deployment as the potential tool for mitigating human elephant conflict by repelling individual elephants from the potential farm area.

Age and sex differences

Drone substantiated a useful tool for assessing behavioral responses of elephants, there was no significant differences between age-sex specific structure of the individual elephants related to behavioral responses this entails that individual elephant strongly reacted to deployment of drone irrespective of age or sex structure where by running, aggressive and ear flipping dominated by 85.6%. These results are supported by study of (Fishlock, 2016) who found that individual elephants will respond similarly to deployment of drone regardless of their age or sex specific structure. Furthermore, individual elephants were strongly reacted to fleeing disparate their age- sex specific structure but depending on drone approach, this show that individual elephants will start to flee as the drone become closer i.e., less than 30 meters. Therefore, drone will be useful tool for wildlife managers dealing with human elephant conflict.

Elephants group to field deployment of drone

The findings of this research confirm that elephants responded strongly to deployment of drone depending on drone approach distances (distance from elephants to drone) that is horizontal distance, as the drone approached, elephant groups would group together quickly and reacts to fleeing as the drone came around less than 30m (horizontal distances) that is distances from elephants to the drone, also at height within 20 m. These findings are consistence with the study of (De, 2021) which found that, elephants will flee as the drone approaches closer within 50m.

Therefore, employing drone will help to repelling elephants without confronting the life of human that are living adjacent protected area and avoiding use of local method that risking the life of human and elephants (Osborn & Parker, 2002) although drone is relatively inefficient especially in forest area this because of high height elephants would ignore the drone.

Repelling of elephants using drone

The use of drone in repelling of elephants opens up interesting perspectives. Up to now, no other investigations had shown the magnitude of fleeing by elephants in response to drone deployment.

Therefore, this study revealed that the magnitude of fleeing by individual elephants was 90 m and 85.5 m for group elephants respectively. Therefore, deployment of drone to repelling elephants from the potential farms will be successfully and this will reduce the use of local methods such as use of drums to fright elephants, use of fire crackers and use of guns to repelling elephants.

CONCLUSION AND RECOMMENDATIONS

This study revealed that elephants strongly react to deployment of drones. This implies that drones are useful for repelling elephants from the potential farm areas and that an opportunity exists for future development and ensuring sustainable conservation of elephants as we know that elephants are endangered species. Park Managers need to devise their strategies for mitigating human elephant conflict in a safe and efficient manner in order to reduce the negative effects caused by elephants. Through deployment of drones will also reduce operational costs like use of fire crackers and use of guns in repelling of elephants

Park managers call for cost effective and innovative solution to solve the problem of human elephant conflict I strongly recommend that park managers they should employ drone to reduce effects caused by elephants because they are cost effective. Also, to ensure conservation of elephants from poaching as resulted from human-elephant conflict

ACKNOWLEDGEMENT

First, praises and gratitude to the Almighty God, for his blessings throughout my research work to complete the research successfully. I am extremely grateful to my parents for their love, prayers, caring, and sacrifices for educating and preparing me for my future. I would like to precise my deep and sincere thankfulness to my research supervisor, Dr. James V. Wakibara for his support, advice, inspiration and providing invaluable guidance all over this research. I would like to give special thanks to Assistant Conservation Commissioner of Mkomazi National Park, Mr. Emmanuel L. Moirana for allowing me to do this interesting study in Mkomazi National Park and he gave me great assistance during data collection period at Mkomazi National Park. Also, I am overwhelmed in all humbleness and gratefulness to acknowledge my depth to Even Chilagwire for his assistance as assistant drone pilot and other contributions toward completion of my research work. Last but not least, I would like to extend thanks the management of the Tanzania National Parks (TANAPA) for allowing me to conduct my research project in Mkomazi National Park.

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THE 13TH TAWIRI SCIENTIFIC CONFERENCE,

GENERAL PROGRAMME 06th-08th DECEMBER 2021

PARTICIPANTS REGISTRATION-SUNDAY				
DATE	**TIME**	**VENUE**		
5/12/2021	10:00-17:00	Participants Registration		AICC- On desk registration and other logistics
DAY ONE-MONDAY				
6/12/2021	8:00 – 9:00	Registration, Exhibition Visitation and housekeeping		
	9:00-10:30	**SIMBA HALL**	**TAUSI HALL**	**OLDONYOLENGAI HALL**
		OPENING CEREMONY MINISTER-MNRT	-	-
	10:31-11:00	**HEALTH BREAK**		
	11:10-11:45	Plenary session:- Paper 1 **Dr Simon Mduma**		
	11:50 – 13:11	Parallel session 1	Parallel session 2	Parallel session 3
	13:11 – 14:00	**LUNCH BREAK**		
	14:00-14:45	Plenary session:- Paper 2 **Prof. Salome Misana**		
	14:50 – 16:30	Parallel session 1	Parallel session 2	Parallel session 3
	17:31-17:00	**HEALTH BREAK**		
	17:01 – 18:00	Round Table discussion 1	Seminar 1	Round Table Discussion 2
	19:00-21:00	**EVENING GATHERING AND NETWORKING**		

DAY TWO-TUESDAY				
7/12/2021	8:30 – 9:15	Plenary session:- Paper 3 **Prof. Noah Sitati**		
	9:20- 10:40	Parallel session 4	Parallel session 5	Parallel session 6
	10:41 – 11:00	**HEALTH BREAK**		
	11:00 – 13:00	Parallel session 4	Parallel session 5	Parallel session 6
	13:00 – 14:00	**LUNCH BREAK**		
	14:00-14:45	Plenary session:- Paper 4 **Prof. Abiud Kaswamila**		
	14:50 – 16:30	Parallel session 4	Parallel session 5	Parallel session 6
	16:31-17:30	**POSTER PRESENTATIONS**		
	16:31-17:00	**HEALTH BREAK**		
	17:00-18:20	Seminar 2	Round Table Discussion 3	Round Discussion 4

DAY THREE-WEDNESDAY				
8/12/2021	8:30 – 09:15	Plenary session:- Paper 5 **Prof. Sam Maghimbi**		
	09:20– 10:40	Parallel session 7	Parallel session 8	Parallel session 9
	10:41 – 11:00	**HEALTH BREAK**		
	11:00 – 13:00	Parallel session 7	Parallel session 8	Parallel session 9
	13:00 14:00	**LUNCH BREAK**		
	14:00-15:40	Parallel session 7	Parallel session 8	Parallel session 9
	15:41 – 16:00	Key Message Director of Research-TAWIRI	-	-
	16:01 – 16:20	**HEALTH BREAK**		
	16:21-16:30	**RESOLUTIONS**		
	16:31-17:00	**CLOSING REMARKS: PERMANENT SECRETARY MNRT**		

DAILY PROGRAMME

PRE-CONFERENCE EVENTS SUNDAY 5TH DECEMBER 2021

Time	Activity /Symposium	Location/Venue	Responsible
10:00-17:00	Participants arriving & Registration	AICC – Reception registration desk	Organizing Committee

DAY ONE MONDAY 6TH DECEMBER 2021

EVENTS/PRESENTATIONS: SIMBA CONFERENCE HALL				
S/N	**Time**	**Event/Paper**	**Responsible**	**Remarks**
i)	07:00 –08:30	Registration & Logistics	Organizing Committee	
ii)	08:30 –08:40	Housekeeping	Moderator	Moderator
iii)	08:40 -09:00	Exhibition visitation	DG-TAWIRI	OC
v)	09:00-09:05	Special greetings	WWF-TAnzania	Moderator
vi)	09:05-09:10	Special greetings	UAG-Group	Moderator
vii)	09:10-09:15	Special greetings	USAID	Moderator
Viii)	09:15-09:20	Special greetings	UNEP	Moderator
ix)	09:20-09:35	Introductory remarks	DG- TAWIRI	Moderator
x)	09:35-09:50	Welcome remarks	TAWIRI-BOARD	Moderator
xi)	09:50-10:20	Opening Speech	Guest of Honor-Minister - MNRT	Moderator
xii)	10:20-10:30	Group Photo	OC	Moderator
	10:30-11:00	**TEA/COFFEE BREAK**	**All**	Moderator

DAY ONE: MORNING SESSION PLENARY PRESENTATION - PAPER 1				
S/N	**Time**	**Event/Paper**	**Presenter**	**Chairperson**
1	11:00-11:45	Sustainability of Wildlife Population Diversity Under Increasing Human Population: The 2030 Agenda for Sustainable Development	Dr. Simon Mduma	Prof. Salome Misana

DAY ONE: MORNING PARALLEL SESSION 1: SIMBA CONFERENCE HALL SUB-THEME: WILDLIFE ECOLOGY AND ECOLOGICAL INTERACTIONS				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
2	11:50-12:10	Keystone predation by lions	Veldhuis, M *et al.*	Prof. Yunus Mgaya
3	12:11-12:30	Land use and habitat selection by small mammals in the Tanzanian Greater Serengeti Ecosystem	Monica T. Shilereyo *et.al.,*	
4	12:31-12:50	Dynamics of herbivore distribution and habitat selection in the Greater Serengeti Ecosystem, Tanzania	Hamza Kija *et. al.*	
5	12:51-13:10	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 *et al.*	
	13:11-14:00	**LUNCH**		OC/MC
AFTERNOON SESSION- PLENARY PRESENTATION PAPER 2 SIMBA HALL				
6	14:00-14:45	The role of land-use planning in conserving biodiversity and improving food security amid changing land use and land cover: the Case of East African Region	Prof. Salome Misana	Prof. Noah Sitati
AFTERNOON-PARALLEL SESSION 1: SIMBA CONFERENCE HALL SUB-THEME: *Wildlife ecology and ecological interactions….*				
7	14:50-09:10	Giraffe (*Giraffa camelopardalis tippelskirchii*) population structure and distribution vary across land use and management types in the Tsavo Mkomazi landscape.	Muthiuru Chege *et. al.*	Dr. Ezekiel Dembe
8	15:11-15:30	Long-term telemetry data reveal dramatic changes in the Serengeti wildebeest migration	Morrison T.A., *et al.*	
9	15:31-15:50	Understanding population trends in avian scavengers in Tanzania's southern parks	Corinne Kendall *et al.*	
10	15:51-16:10	Characterising Wildlife Behavioural Responses to Tourists and Tourism Infrastructure Using Integrated Step Selection Analysis	William McLellan *et al.* ***Virtual***	
11	16:11-16:30	Ecological linkages: their importance to conserving biodiversity in the eastern arc mountains	William D. Newmark ***Virtual***	
	16:31-17:00	**HEALTH BREAK**		

		Round Table Discussion One	presenter	Moderator
12	17:01-18:00	Emerging Technologies in community Natural Resources Management	Charles Trout *et al.*	Dr. Philip Muruthi
E N D O F D AY ONE				
	19:00-21:00	EVENING SCIENTIFIC GATHERING AND NETWORKING		
		Special messages from: Director Wildlife Division, Otterlo Bussiness Corporation, Tanzania People and Wildlife, Grumeti Fund, AiCC and African Wildlife Foundation		

DAY ONE: MORNING PARALLEL SESSION 2: TAUSI CONFERENCE HALL SUB-THEME: EMERGING TECHNOLOGIES AND CONSERVATION				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
13	11:50-12:10	Using genomic tools to inform conservation management decisions	Barbara K. Mable *et. al.*	Bupe Mwambingu
14	12:11-12:30	Experimental validation of specialised questioning techniques in conservation	Harriet Ibbett *et. al.* ***Virtual***	
15	12:31-12:50	A machine learning approach for minimizing the effects of fire on flora and fauna in Tanzania	Mathew Langen *et. al.*	
16	12:51-13:10	Using Innovation and Existing Technology to Facilitate the Protection of Mountain Gorillas in the Virunga and Bwindi Impenetrable National Parks	Shounak Barat *et. al.*	
	13:11-14:00	**LUNCH BREAK**		**OC/MC**
	14:00-14:45	**PLENARY PRESENTATION AT SIMBA HALL-PAPER 2**		
AFTERNOON PARALLEL SESSION 2				**Chairperson**
17	14:50-09:10	Lion's behavioural adaptations to a multiuse landscape	Ingela Jansson *et al.*	Matt Perry

SUB THEME: NATURE AND CULTURAL HERITAGE TOURISM DEVELOPMENT				
18	15:11-15:30	Natural history collections outline 100 years of faunal change	Christine Ngereza *et al.*	Matt Perry
19	15:31-15:50	Nature conservation as a decisive factor toward the development of cultural tourism	Lasway Agapiti *et al*	
	SUB-THEME: MONITORING OF WILDLIFE POPULATION AND THREATENED SPECIES			
20	15:51-16:10	Understanding cause of the decline of near threatened Puku (*Kobus vardonii*) antelope: Using DNA metabarcoding to assess the impact of competitive exclusion by cattle in Kilombero Valley, Tanzania	Koggani Dickson *et al.*	
21	16:11-16:30	Assessment of solar powered led lights as a tool for protection against carnivores around Ruaha national park	Roberts, J. Malulu *et.al.*	
22	16:31-16:50	Approaches and Techniques for Managing the Human-Elephant Conflict in Western Serengeti, Tanzania	Isaac Chamba *et. al.*	
23	16:51-17:10	Will the introduction of cable cars will unlock the tourism potential of Mount Kilimanjaro? Perceptions of tprism stakeholders”	Umutoni Peace *et. al.*	
	17:11 – 17:30	**HEALTH BREAK**		
	Workshop/seminar 1		Presenter	**Moderator**
24	17:31-18:20	Use of Wild ID Software for Identification of Giraffe	Jessica Manzak	Dr Wilfred Marealle
	END OF DAY ONE			
	19:00-21:00	**EVENING SCIENTIFIC GATHERING**		

DAY ONE: MORNING PARALLEL SESSION 3: OLDONYOLENGAI-HALL SUB-THEME: CLIMATE CHANGE AND - ECOLOGICAL RESILIENCE				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
25	11:50-12:10	Rainfall and temperature patterns and their influence on wildlife ecosystems in Mikumi National Park, Tanzania.	Deusdedith Bwenge, *et. al.,*	Dr. Josephine Smith
26	12:11-12:30	Impact of gender inequality on climate change adaptive capacity and Livelihoods For vulnerable social groups around Mikumi and Ruaha national park, Tanzania	Asanterabi Lowassa *et. al.,*	
27	12:31-12:50	Effect of climate change on aquatic biodiversity: A case of common Natron tilapia and great white pelicans at lake Natron RAMSAR site	Dickson Wambura *et. al.,*	
28	12:51-13:10	Between hunter and climate: The effects of hunting and environmental change on faecal glucocorticoid levels in 4 large ungulates in the Ruaha-Rungwa Ecosystem, Tanzania	Kwaslema Malle Hariohay *et al.*	
	13:10–14:00	**LUNCH - BREAK**		OC/MC

14:00-14:45	**PLENARY PRESENTATION AT SIMBA HALL-PAPER 2**			
DAY ONE: AFTERNOON PARALLEL SESSION 3: OLDONYOLENGAI-HALL **SUB-THEME:** ***Climate Change and - ecological resilience……..***				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
29	14:50-09:10	A predictive framework for understanding the response of Serengeti ungulates to climate change.	Majaliwa M. Masolele *et. al.,*	**Prof. Linus Munishi**

30	15:11-15:30	Good-bye to Chimpanzees (*Pan troglodytes schweinfurthii*) under warmer climates? Implication for Conservation Action Planning in Tanzania	Sood A. Ndimuligo *et. al.,*	**Prof. Linus Munishi**
31	15:31-15:50	Linking Climate Change Adaptation and Conservation in the Land-use Planning Process. An example from Greater Gombe Ecosystem in Western Tanzania.	Fadhili Mlacha *et. al.,*	
32	15:51-16:10	The use of herbarium specimen records in identifying biodiversity conservation gaps, in Tanzania: A case study of Rubiaceae family.	Immaculate K. Constantine *et al.,*	
33	16:11-16:30	Status of land use and land cover changes in a few selected villages in the eastern Serengeti ecosystem	Franco P. Mbise *et. al.*	
	SUB-THEME-HUMAN-WILDLIFE INTERACTION			
34	16:31-16:50	Perceptions and attitudes of people towards Indian house crow (*Corvus splendens*): A case study of Tanga and Dodoma regions, Tanzania	Theresia R. Ndanu *et. al.*	
35	16:51-17:10	Legalizing access to wild meat: People's perceptions and factors influencing access to wild meat in Dodoma.	McDonald Gregory Mlemwa *et. al.*	
	17:11-17-30	**HEALTH BREAK**		
		Round table discussion 2	**Organizers**	**Moderator**
36	17:31-18:20	The challenges of enhancing tourism and livelihoods in southern Tanzania	John Bukombe *et al.*	Dr. Neduvoto Mollel
END OF DAY ONE				
19:00-21:00		**EVENING SCIENTIFIC GATHERING: AICC NYASA HALL**		

DAY TWO: TUESDAY 07TH DECEMBER 2021

DAY TWO: MORNING SESSION- PLENARY PRESENTATION PAPER No. 3 SIMBA CONFERENCE HALL				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
37	08:30-09:15	Promoting capacity of local communities to pursue sustainable livelihood strategies to help conserve the wild: The 2030 Agenda for Sustainable Development	Prof. Noah Sitati	Prof. Michiel Veldhuis
DAY TWO: MORNING PARALLEL SESSION 4: SIMBA CONFERENCE HALL SUB-THEME: HUMAN-WILDLIFE INTERACTIONS				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
38	09:20-09:40	Trials of a novel olfactory elephant deterrent in the Kilombero Valley, Tanzania	Josephine B. Smit *et al.*	Dr. Ingela Jansson
39	09:41-10:00	Patterns of crop-raiding by African elephants (*Loxodonta africana*) in farms around south-western Serengeti ecosystem	Revocatus Meney *et al.,*	
40	10:01-10:20	Effects of snakebite on the livelihood of local communities in Ngorongoro district, Arusha region	Tito J. Lanoy *et al.*	
41	10:21-10:40	Responses of local community towards the establishment of Ngarambe-Tapika wildlife management area in Rufiji district, Tanzania.	Rose G. Mdendemi *et.al.,*	
	10:40 – 11:00	**HEALTH BREAK AND POSTER PRESENTATION**		

42	11:01-11:20	Urban wildlife management – a pilot study about urban crows	Kövér, L.*et.al.,*	Prof. Jafari Kideghesho
43	11:21-11:40	Innovatively engaging village scouts enhance wildlife conservation under informal wildlife settings in Mwanga District, Tanzania.	Maria Mbata *et al*	
44	11:41-12:00	Assessment of behavioural responses of elephants on drone deployment in Mkomazi National Park, Northern Tanzania	George R. George *et al.*	

45	11:45-12:00	The Status of Human- lion Conflicts Around Ugalla Ecosystem, in Western Tanzania	Jonathan L. Kwiyega *et al.*	
46	12:01-12:20	Economics of Potential Income Generating Activities as Land Use Options around Protected Areas. A case of REDD+ Program Villages in Kilosa District, Tanzania.	Renatus Paul *et al.*	
47	12:21-12:40	Dynamics of human-elephant conflicts in villages surrounding Ruaha national park, southern highlands, Tanzania	Lucia Romward *et. al.,*	
48	12:41-13:00	The coexistence between wildlife and human activities in the Makuyuni wildlife corridor	Emmanuel Lyimo *et. al.,*	
13:00 - 14:00		**LUNCH BREAK**		
AFTERNOON PLENARY SESSION- KEYNOTE PAPER PRESENTATION No. 4: SIMBA HALL				
49	**14:01-14:45**	Policy Implications on Human-Wildlife Conflicts and Initiatives in Mitigating the Conservation Challenges	Prof. Abiud Kaswamila	Dr Julius Keyyu

AFTERNOON PARALLEL SESSION 4: SIMBA CONFERENCE HALL SUB-THEME: HUMAN-WILDLIFE INTERACTIONS				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
50	14:50-09:10	Evaluation of the Landscape Conservation Process using the Tsavo-Mkomazi Transboundary landscape.	Nakedi Maputla, *et. al.*	Dr. Amani Ngusaru
51	15:11-15:30	Traditional knowledge on wild edible vegetables consumed by communities around Serengeti ecosystem, northern Tanzania	Richard Lyamuya *et al*.	
52	15:31-15:50	Trophy hunting and Land-use Options in Loliondo Game Controlled Area: A Multicriteria Analysis	Gileard Minja *et al*.	
53	15:51-16:10	Does Human Disturbance and Intra/Inter-specific Competition Affect the Vultures' Feeding Ecology?	Mika Takahashi *et.* ***al.*** ***Virtual***	
54	16:11-16:30	Afrotropical montane birds experience upslope shifts and range contractions along a fragmented elevational gradient in response to global warming	Monte Neate-Clegg *et. al.*, ***Virtual***	
	16:31-17:00	**HEALTH BREAK AND POSTER PRESENTATION**		
		Seminar 2	**Presenter**	**Moderator**
55	**17:00-18:00**	**Discovering Biodiversity Together: Using emerging DNA technologies**	**Bupe Mwambingu**	Dr Anna Czupryna
	E N D O F DAY TWO			

DAY TWO: MORNING PARALLEL SESSION 5: TAUSI CONFERENCE HALL SUB-THEME: BEE ECOLOGY, BEEKEEPING AND API-TOURISM				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
56	09:20-09:40	Exploration of queen rearing techniques to beekeepers as the means of transforming good traits of honeybee colonies for maximizing production	Dula Lugano *et. al.*	Dr. Nicephor Lesio
57	09:41-10:00	Status of demand for honey in Arusha City, Tanzania: The case of honey distribution by Tanzania Wildlife Research Institute (TAWIRI)	Raymond Okick *et al.*	
58	10:01-10:20	Balancing bees and livestock: pastoralist knowledge, perceptions, and implications for pollinator conservation in rangelands, Northern Tanzania	Faith Thomas Mpondo *et al.*	
59	10:21-10:40	Population structure and phenological patterns of *Warburgia ugandensis* in Lushoto District, Tanzania	Pima, N.E *et al.,*	
	10:40 – 11:00	**HEALTH BREAK AND POSTER PRESENTATION**		
60	11:01-11:20	Antibacterial activity of Kibaha honey bees propolis against bacteria *Escherichia coli*.	Octavian Francis Mlenga *et. al.*	Fredrick Ojija
61	11:21-11:40	Capacity strengthening on queen rearing for biodiversity conservation and improved livelihood in Tanzania	Frida Kundy *et. al.*	
62	11:41-12:00	Floral resources mediate the positive effect of low grazing intensity on the east African bee assemblages	Julius V. Lasway *et. al.*	
63	11:45-12:00	Indigenous knowledge of beekeepers on morphology and behaviour variations of honeybees in Tanzania	Nicephor Lesio *et. al.*	
64	12:01-12:20	Cost-Benefit Analysis for EAMCEF Beekeeping and Dairy Cow Projects in the Eastern Arc Mountains, Tanzania	Pilly Kagosi *et. al.*	
65	12:21-12:40	Does honey colour have any implication for antimicrobial activity?	Victor Kakengi *et. al*	
66	12:41-13:00	Understanding the relation-ship between parasite load and body condition of Masai Gi-raffes in Tarangire – Manyara ecosystem.	Victoria Fortunatus Mkessa	
13:00 - 14:00		**LUNCH- BREAK**		

PLENARY PRESENTATION - PAPER 4 AT SIMBA HALL				
PARALLEL SESSION 5: TAUSI CONFERENCE HALL **SUB-THEME: INDUSTRIALIZATION, EMERGING ECONOMIC OPPORTUNITIES, INFRASTRUCTURE DEVELOPMENT AND BIODIVERSITY CONSERVATION**				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
67	14:50-09:10	Assessing the impact of infrastructure development on elephant movement patterns in critical ecosystems of northern Tanzania	Alex Lobora *et.al.,*	Dr Grant Hopcraft
68	15:11-15:30	Are infrastructure development pose adverse impacts on biodiversity in protected areas? A Case of Selected Valued Environmental Components in Ukutu-	Chelestino Balama *et.al.,*	
69	15:31-15:50	Impact of infrastructure development on wildlife in critical ecosystems of northern Tanzania	Julius Keyyu *et.al.,*	
70	15:51-16:10	National Forest Policy and Industrialization: Critical analysis of 1998 forest policy on the perspective of industrial economy in Tanzania	Numan S. Amanzi, *et.al.,*	
71	16:11-16:30	Challenges facing the introduction of SMART patrols in a game reserve, western Tanzania	Paulo Wilfred, *et. al.*	
	16:31-17:00	**HEALTH BREAK POSTER PRESENTATION**		
	16:31-17:30	**Poster Presentation-Display area**		
		Round table 3	**Presenter**	**Moderator**
72	**17 :00-18**	Fencing for conservation – Insights from the Ikorongo pilot electric fence	Kristen Denninger Snyder *et. al.,*	Yustina Kiwango
	END OF DAY TWO			

DAY TWO: MORNING PARALLEL SESSION 6 OLDONYOLENGAI CONFERENCE HALL SUB-THEME: WILDLIFE ECOLOGY AND ECOLOGICAL INTERACTIONS				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
73	09:20-09:40	Assessing large carnivore population status in vast landscapes: A case study of leopard and other species in Selous-Nyerere	Charlotte Searle	Kwaslema Malle Hariohay
74	09:41-10:00	Spatial-temporal comparisons in wildlife and vegetation following a decrease of livestock pressure between Serengeti National Park and the adjacent village lands	Kiwango, Y. A *et.al.,*	
75	10:01-10:20	Abundance and diversity of hawkmoths in forest edges and surrounding farmlands in Amani Nature Reserve	Adelaide Sallema	
76	10:21-10:40	An Analysis of Elephants' Movement Data in Sub-Saharan Africa Using Clustering.	Gregory Glatzer *et. Al* ***Virtual***	
	10:40 – 11:00	**HEALTH BREAK**		
77	11:01-11:20	Estimating and Assessing Chimpanzee Populations and Threats in the Masito Ugalla Ecosystem, Tanzania	Deus C. Mjungu	G. Meng'ataki
78	11:21-11:40	Movement behaviour and home range size of Roan and Sable antelopes in Usangu Area – Ruaha National Park, Tanzania	Emmanuel H. Masenga	
79	11:41-12:00	Lion and spotted hyena distributions within a buffer area of the Serengeti-Mara ecosystem	Stanslaus B. Mwampeta	
80	11:45-12:00	Camera trapping and spatially explicit capture-recapture for the monitoring and conservation management of lions	Paolo Strampelli	

81	12:01-12:20	Species diversity and abundance of large mammals in different conservation levels of protected areas in Northern Tanzania	Evaline J. Munisi *et. al.,*	
82	12:21-12:40	An Analysis of Wildlife Seizure Data Distributions using Spatial Clustering	Marvin Jakobs	
83	12:41-13:00	Assessing the impact of infrastructure development on avifauna in critical ecosystems of northern Tanzania	Ramadhani Juma *et al*	
13:00 - 14:00		**LUNCH- BREAK**	**All**	**MC**
PLENARY PRESENTATION - PAPER 4 AT SIMBA HALL				
PARALLEL SESSION 6: OLDONYO LENGAI CONFERENCE HALL				
SUB-THEME: HUMAN-WILDLIFE INTERACTIONS				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
84	14:50-09:10	Response of common Moorland birds toward tourists and their activities on Mount Kilimanjaro	Thomas Joseph Momburi *et al*	Dr. Devolent Mtui
85	15:11-15:30	Assessment of Trade Flows of Wildlife Products from Tanzania: The Case of Ruaha Ecosystem, Tanzania	Hillary T. Mrosso *et al*	
86	15:31-15:50	Economics of Potential Income Generating Activities as Land Use Options around Protected Areas. A case of REDD+ Program Villages in Kilosa District, Tanzania	Renatus Paul *et al*	
87	15:51-16:10	What role might invasive plants play in the protection and restoration of Tanzania's montane forests?	Strange, E.F, *et. al.*	
88	16:11-16:30	Malignant Catarrhal Fever: A case study for Ecosystem Health	Mappi T. *et. al*	

	16:31-17:00	**HEALTH BREAK AND POSTER PRESENTATIONS**		
	16:31-17:30	**Poster Presentation-Display area**		
		Round table discussion 4	**Presenter**	**Moderator**
89	**17:31-18:20**	20 years of community-based- wildlife management areas (WMAs) conservation model in Tanzania: does it hold water for the future of wildlife management in Tanzania?	Fortunata Msoffe *et al.*	Emmanuel Lyimo
	E N D O F DAY TWO			

DAY TWO: POSTER PRESENTATIONS: 07TH DECEMBER 2021

Chairperson: Hillary Mushi

S/N	Title	Author(s)	Sub-theme
90	Identification of plant sources of pollen grains in honey from the University of Dodoma apiary	Baraka Kombe and Ignas Safari *et. al.*	Bee ecology, Beekeeping and Api-tourism
91	Beekeeping, people's livelihood and ecosystem Sustainability in a forest conservation area, Tanzania	Deodata V. Mtenga *et. al.*	Bee ecology, Beekeeping and Api-tourism
92	People's awareness, knowledge and perceptions toward bee–pollinators	Fredrick Ojija	Bee ecology, Beekeeping and Api-tourism
93	Beekeeping and environment conservation project	Stephen R Esau, *et. al.*	Bee ecology, Beekeeping and Api-tourism
94	Predicting the Impacts of Climate Change on the potential suitable habitat distribution of House Crows (*Corvus splendens*) in Tanzania	Sood A.Ndimuligo, *et. al.*	Climate Change and -ecological resilience

S/N	Title	Author(s)	Sub-theme
95	Factors affecting cattle movement in a high-risk Malignant Catarrhal Fever (MCF) area, Tanzania	Bakari Mtili *et. al.*	Ecosystem Health and Wildlife Diseases
96	Reservoir Dynamics of Rabies in Southeast Tanzania and the roles of cross-species transmission and domestic dog vaccination	Kennedy Lushasi, *et. al.*	Ecosystem Health and Wildlife Diseases
97	Conservation genetics of pheasants of Genus Lophura	Leonard J. Haule, *et. al.*	Emerging Technologies and Conservation
98	UAV-based Wildlife Habitats Assessment in Burunge Wildlife Management Area, Tanzania	Lazaro J. Mangewa	Emerging Technologies and Conservation
99	Impact of daemon African mole rat on grassland vegetation, a case study of emburbul depression, Ngorongoro	Lekitonyi Maura	Habitat and Biodiversity Conservation
100	Factors influencing land use and land cover changes in the Greater Serengeti Ecosystem (1995-2015), Tanzania	Hamza K Kija, *et. al.*	Habitat and Biodiversity Conservation
101	Classification of Existing and Novel Wildlife plant species based on Deep Neural Network Data-driven Methods.	Jamal F. Banzi, *et. al.*	Habitat and Biodiversity Conservation
102	The influence of *Vachellia zanzibarica* encroachment on abundance and distribution pattern of giraffe's in Saadani National Park.	Kaiza R. Kaganzi, *et. al.*	Habitat and Biodiversity Conservation
103	Resource Assessment for Mkinga, Tanga and Pangani Mangrove Forest Reserves	Kajia, Y. S, *et. al.*	Habitat and Biodiversity Conservation
104	Phylogenetic relationships, distribution, and abundance of *Charaxes mtuiae* in the Kihansi Gorge Forest in Morogoro, southern Tanzania.	Devolent Mtui *et al.*	Habitat and Biodiversity Conservation

S/N	Title	Author(s)	Sub-theme
105	COVID-19 pandemic episode and its socio-economic effects to local communities adjacent to Burunge Wildlife Management area within Tarangire-Manyara Ecosystem, Tanzania	Francis Chebby *et. Al.*	Habitat and Biodiversity Conservation
106	Comparison of the effects of a broad-spectrum herbicide and a bio-herbicide on insect flower visitation in the Serengeti ecosystem, Tanzania	Mecklina M. Mbundi, *et. al.*	Habitat and Biodiversity Conservation
107	Insect diversity in the wild flowering strips along with arable fields.	Neema Kilimba, *et. al.*	Habitat and Biodiversity Conservation
108	The social distancing of individuals in a lion translocation raises prospects for filial infanticide in a captive Serengeti lion pride.*	Alphonce Msigwa	Habitat and Biodiversity Conservation
109	Preliminary findings on the Factors affecting the sustainability of wildlife corridors joining Ngorongoro Conservation Area and adjacent protected areas in Northern Tanzania: A chronological study from the 1950s to 2020	Cuthbert L. Nahonyo, *et. al.*	Habitat and Biodiversity Conservation
110	Viability assessment of the last remaining wildlife corridors in southern Tanzania	Bukombe J. *et al.,*	Habitat and Biodiversity Conservation
111	Non-local effects of human activity on the spatial distribution of wildlife in Serengeti National Park, Tanzania	Cyrus Kavwele *et.al.,*	Human-Wildlife Interactions
112	Conservation Planning and Viability in the Selous-Niassa Trans-Frontier Conservation Area, Southern Tanzania: Safe corridor for People and Wildlife	Hamza K Kija *et. al.*	Human-Wildlife Interactions
113	Experimental study onhuman-baboon conflicts mitigation in Rombo district, Kilimanjaro	Emmanuel Usangila et al	Human-Wildlife Interactions

S/N	Title	Author(s)	Sub-theme
114	Scaling -up non-lethal mitigations to reduce Human-Elephant conflicts in Tanzania	Janemary Ntalwila, *et. al.*	Human-Wildlife Interactions
115	Assessment of Human-Carnivores Conflicts in grazing area in Ngorongoro conservation area.	Joel Miraji, *et. al.*	Human-Wildlife Interactions
116	Communal Perception of Human-Elephant Coexistence in South-Western Serengeti Ecosystem	Revocatus Meney	Human-Wildlife Interactions
117	Case report on emerging poisoning of elephants in Ngorongoro Conservation Area	Dickson M. Wambura *et.al.,*	Human-Wildlife Interactions
118	Socio-Economic Determinants of household income in Esilalei and Oltukai villages in Monduli District, Tanzania	Omondi E1, *et. al.*	Human-Wildlife Interactions
119	Drivers of Human-Wildlife Conflicts in villages contiguous to Mikumi and Udzungwa National Parks, Tanzania	Victor Kakengi, *et. al.*	Human-Wildlife Interactions
120	Mammalian roadkill patterns on gravel road networks in the Serengeti ecosystem, northern Tanzania	Rajab Mikole *et. al.*	Industrialization, emerging economic opportunities, infrastructure development and biodiversity conservation
121	Up-scaling production and commercialization of biomass briquettes for reducing invasive plants in Ngorongoro Conservation Area	Jerome Kimaro, *et. al.*	Natural Resource Policies and Good Governance
122	Environmental degradation notifications for CBOs in Tanzania	Mathew Langen, *et. al.*	Natural Resource Policies and Good Governance
123	Rangeland Guardians: women entrepreneurs for rangeland restoration	Rob Critchlow, et. al.	Natural Resource Policies and Good Governance
124	Assessment of Water Quality of Rivers at northern Serengeti National Park (SNP), Parkinyigoti and Loliondo Game Controlled Area	Masoud S Masoud, *et. al.*	water resources and wetland conservation

S/N	Title	Author(s)	Sub-theme
125	Seasonal variation in uptake of some selected metals in *Cynodon dactylon (L.) Pers.* grass in Serengeti National Park (SNP) and some adjacent villages	Masoud S Masoud, *et. al.*	water resources and wetland conservation
126	Assessment of Water Quality of Rivers at South and Western Serengeti National Park (SNP) at Lamadi and Makao villages	Masoud S Masoud, *et. al.*	water resources and wetland conservation
127	Contemporary Investigation of Environmental Challenges and Opportunities along the Msimbazi Valley: A Look for Unexploited Prospects	Miraji Hossein, *et. al.*	water resources and wetland conservation
128	Butterfly distribution in different habitat types of the Moyowosi Game Reserve, Western Tanzania.	Ally K. Nkwabi et al	Wildlife Ecology and Ecological Interactions
129	Assessment of Biodiversity Occurrences by using multiple techniques in Burigi- Chato National Park in North-western Tanzania: An implication for further inventories	Alphonce Msigwa *et. al.*	Wildlife Ecology and Ecological Interactions
130	Association between genital ulceration and body condition of olive baboon (*Papio anubis*) in the Lake Manyara National park	Emmanuel H. Lyimo *et. al.*	Wildlife Ecology and Ecological Interactions

DAY THREE: WEDNESDAY 08th DECEMBER 2021

DAY THREE: MORNING PLENARY SESSION- KEYNOTE PAPER PRESENTATION No. 5 SIMBA CONFERENCE HALL				
S/N	**Time**	**Paper**	**Presenter**	**Chairperson**
131	8:30-9:15	The implication of various sectoral policies and legislations for the future of Biodiversity Conservation and community's livelihood	Prof. Sam Maghimbi	Prof. Abiud Kaswamila

DAY THREE: MORNING PARALLEL SESSION 7: SIMBA CONFERENCE HALL SUB-THEME: NATURAL RESOURCE POLICIES AND GOOD GOVERNANCE				
S/N	**Time**	**Event/Paper**	**Presenter**	**Chairperson**
132	9:20-9:40	Mapping communal resources to better manage livestock production in northern Tanzania	Ekwem, Divine *et al.,*	Thadeus Binamungu
133	9:41-10:00	Modelling household well-being and poverty trajectories: An application to Esilalei and Oltukai Villages of Monduli District, in Tanzania	Omondi *et al.,*	
134	10:01-10:20	Developing a Decision Support and Alert System to Inform Conservation Management Decisions in Western Tanzania	Lilian Pintea *et al.,*	
135	10:21-10:40	The influence of Climate Change on the biota of the Serengeti savanna ecosystem	Simon A.R. Mduma *et al.,*	
	10:40–11:00	**HEALTH BREAK AND POSTER PRESENTATIONS**		
SUB-THEME:- NATURAL RESOURCE POLICIES AND GOOD GOVERNANCE				
136	11:00-11:20	Multiple anthropogenic pressures challenge the effectiveness of protected areas in western Tanzania	Richard Giliba *et al.,*	Prof. Eivin Røskaft
137	11:21-11:40	Land use planning as a tool to Natural Resource Management and Good Governance in Africa's Protected Areas	Anastacia W. Mwaura *et al.,*	
138	11:41-12:00	Socio-economic and Conservation Effects of Banning Live Wild Animals Trade: The Case of Communities Bordering Nilo Nature Forest Reserve, Tanzania	Abdallah S.Saidi *et al.,*	

139	11:45-12:00	Awareness and Involvement of local communities' adjacent Kihansi catchment in the conservation of the re-introduced Kihansi spray toads (Nectophrynoides)	Atuhombye Sigala *et al.,*	
140	12:01-12:20	Assessing the impact of infrastructure development on flora in critical ecosystems of northern Tanzania	Bukombe *et al.,*	
141	12:21-12:40	Lessons from Land Use Planning Processes that Bridged the Planning-Implementation Gap in Tanzania	David Williams *et al.,*	
142	12:41-13:00	30 years of Roots & Shoots Tree Planting Success in Tanzania	Japhet J.Mwanang`ombe *et al.,*	
	13:00-14:00	**LUNCH**		
143	14:00-14:20	Impact of electric fencing on elephant (*Loxodonta africana*) movement and utilization of agricultural areas. Case study: Ikorongo game reserve	Loyce M. Majige *et al.,*	Dr. Laly Lichtenfeld
144	14:21-14:40	Effects of electric fencing on wildlife habitat utilization and vegetation recovery in the western Serengeti, Tanzania	Michael Honorati Kimaro *et al.,*	
145	14:41-15:00	Electric fence as a mitigation tool for human-elephant conflict in Western Serengeti: The community perspectives Running head: Electric fence as a human-elephant mitigation tool	Maria Matata *et al.*	
146	15:01-15:20	Using individual values to understand perceptions of protected areas.	Leejah Dorward, *et. al.* ***Virtual***	
147	15:21-15:40	How do wildebeest and zebra balance the trade-off between risks and resources when crossing large rivers?	ShayaVan Houdt ***Virtual***	
	15:41-16:00	**Updates from the Directorate of research**	***Director of Research***	**Dr Keyyu**
	16:01-16:20	**HEALTH BREAK**		

	16:21-16:30	**Resolutions**	
	16:30-17:00	**CLOSING REMARKS- SIMBA CONFERENCE HALL**	

END OF DAY THREE – END OF THE 13TH TAWIRI SCIENTIFIC CONFERENCE THANK YOU ALL FOR MAKING THIS EVENT ONE OF THE SUCCESS CONFERENCES

DAY THREE: 8th DECEMBER 2021: MORNING PARALLEL SESSION 8: TAUSI CONFERENCE HALL

SUB-THEME: WILDLIFE ECOLOGY AND ECOLOGICAL INTERACTIONS

S/N	Time	Event/Paper	Presenter	Chairperson
148	9:20-9:40	Preliminary findings: the influence of seasonality and habitat structure on elevational distributions of butterflies in the Uluguru Nature Reserve, Tanzania	Devolent Mtui, *et.al.,*	Dr. Enos omondi
149	9:41-10:00	Rainfall and fire drive annual variation in grazing succession of migratory herbivores in the Serengeti ecosystem	Michael Anderson *et.al.,*	
150	10:01-10:20	Long-distance species needs landscape Management Approach: A case of wildebeest in Northern Tanzania	Edward M. Kohi *et. al.*	
	SUB-THEME: HABITAT AND BIODIVERSITY CONSERVATION			
151	10:21-10:40	Impact of agro-pastoralism on wildlife and livestock forage resources availability in western Serengeti and Ugalla ecosystem	Pius Yoram Kavana *et.al.,*	
	10:41 – 11:00	**HEALTH BREAK AND POSTER PRESENTATION**		
152	11:00-11:20	Status of Endangered Ashy Red Colobus Monkeys (*Piliocolobus tephrosceles*) in the Burigi-Chato National Park: A preliminary assessment for future surveys	Alphonce Msigwa	Shadrak Kamenya

153	11:21-11:40	Diversity of termites and its economic implications at SUA main campus in Morogoro Tanzania	Flora Ngowi *et al.,*	Shadrak Kamenya
154	11:45-12:00	Avifauna in relation to habitat disturbance in Wildlife Management Areas of the Ruvuma miombo ecosystem, Southern Tanzania.	Ally K. Nkwabi *et al.,*	
155	12:01-12:20	Investigating the relationship between liana abundance and tropical forest recovery	Alain Ngute *et al.,*	
156	12:21-12:40	Primates as seed-dispersers: does passing through the gut improve seed germination?	Antony Collins *et al.,*	
157	12:41-13:00	Spatial and temporal pattern of wildfires in Masito Ugalla Ecosystem from 2008 to 2019	Baraka N. Mbwambo *et al.,*	
	13:00-14:00	**LUNCH**		
158	14:00-14:20	Species diversity of brood parasite birds and their hosts at the University of Dodoma campus	Francisco Joseph *et. al.*	Dr Cuthbert L. Nahonyo
159	14:21-14:40	Land Use Planning for Ecosystem Conservation: The Case of Wildlife Corridors Restoration in the Western Zone of Tanzania (Tanganyika, Uvinza and Kigoma Districts)	Joseph John Osena *et al.,*	
160	14:41-15:00	Are we ready for Chinese Tourists? Insights from the Tanzanian Safari Industry	Kokel Melubo, *et. al.*	
161	15:01-15:20	Enriching small and medium trees with suitable nest boxes may offset the loss of tree cavities: a study in tropical Africa.	Charles D.Luchagula *et al.,*	

162	15:21-15:40	Improving livestock-based livelihoods: The option for sustainable environmental conservation in Ngorongoro district	Miran B. Miran	
	15:41-16:00	Updates from Directorate of research-Simba Hall	Dr Keyyu-***Director of Research***	
	16:01-16:20	**HEALTH BREAK**		
	16:21-16:30	**RESOLUTION**		
	16:30-17:00	**CLOSING REMARKS- SIMBA CONFERENCE HALL**		
END OF DAY THREE – END OF THE 13TH TAWIRI SCIENTIFIC CONFERENCE THANK YOU ALL FOR MAKING THIS EVENT ONE OF THE SUCCESS CONFERENCES				

DAY THREE 8th DECEMBER 2021: MORNING PARALLEL SESSION 8: OLDONYO LENGAI CONFERENCE HALL **SUB-THEME: ECOSYSTEM HEALTH AND WILDLIFE DISEASES**				
S/N	**Time**	**Event/Paper**	**Presenter**	**Chairperson**
163	9:20-9:40	Status of Giraffe Skin Disease (GSD) in Ruaha National Park	Julius D. Keyyu *et al.,*	Prof. Sara Cleavalent
164	9:41-10:00	Progressive scaling up of domestic dog rabies vaccination across Mara Region	Anna Maria Czupryna *et al.,*	
165	10:01-10:20	Knowledge on Impacts and Potential Health Risks of Bushmeat Hunting and Trade by Communities neighbouring Nyerere National Park, Southern Tanzania	Yohani Rovetha Foya *et al.,*	
166	10:21-10:40	Environmental Pharmaceutically Active Compounds: A Focus on Ecosystem Health and Wildlife Diseases	Asha Ripanda *et al.,*	

	10:40 – 11:00	**HEALTH BREAK AND POSTER PRESENTATION**		
S/N	**Time**	**Event/Paper**	**Presenter**	**Chairperson**
167	11:00-11:20	Trends and Debates on Human-Wildlife Conflicts and its Consequences on Health: The Relevance of One Health Approach in Tanzania	Mikidadi Muhanga *et al.,*	Dr. Robert Fyumagwa
168	11:21-11:40	The Gombe Ecosystem Health Project: 16 years of program evolution and lessons learned	Elizabeth V. Lonsdorf *et al.,*	
169	11:41-12:00	An outbreak of mange in rock and bush hyraxes of Serengeti National Park	Idrissa S. Chuma *et al.,*	
170	11:45-12:00	Understanding the population demographics and threats, including Giraffe Skin Disease, facing giraffes in Southern Tanzania	Jessica Manzak *et al.,*	
171	12:01-12:20	Prevalence of Rickettsia bacteria in small wild mammals in Laikipia County, Kenya	Lekolool *et al.,*	
SUB THEME: Habitat and Biodiversity Conservation				
171	12:21-12:40	Yellow baboon diet from the Issa valley, western Tanzania: Diversity and Annual Variability	J. Mkola *et. al.,*	Dr. Grant Hopcraft
172	12:41-13:00	Distribution and regenerative capacity of the vulnerable African red stinkwood (*Prunus africana*) on the southern slopes of Mount Kilimanjaro	Calvin Lauwo *et al.,*	
	13:00-14:00	**LUNCH**		
173	14:00-14:20	Mapping natural habitat loss and its impact on wildlife in the Selous-Niassa wildlife corridor in southern Tanzania	Emmanuel L. Laizer *et al.,*	
174	14:21-14:40	Ruvuma transboundary landscape predictive elephant distribution modelling	Mathew Langen *et al.,*	
175	14:41-15:00	Trophic webs drive tree establishment in the Serengeti ecosystem	Jason Donaldson *et al.,*	

176	15:01-15:20	Determination of the influence of vegetation structure on butterfly diversity in Arusha National Park	Joseph S. Sikawa *et al.,*	
177	15:21-15:40	Application of spatial planning workflows and solutions for field survey: The case of Chimpanzee Survey in the Masito Ugalla Ecosystem in Western Tanzania	Paul Mjema *et al.,*	
	15:41-16:00	**Updates from Directorate of research-Simba Hall**	**Dr Keyyu-*Director of Research***	
	16:01-16:20	**HEALTH BREAK**		
	16:21-16:30	**RESOLUTION**		
	16:30-17:00	**CLOSING REMARKS- SIMBA CONFERENCE HALL**		

END OF DAY THREE – END OF THE 13TH TAWIRI SCIENTIFIC CONFERENCE
THANK YOU ALL FOR MAKING THIS EVENT ONE OF THE SUCCESS CONFERENCES

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