TANZANIA WILDLIFE RESEARCH INSTITUTE (TAWIRI)

TAWIRI
Tanzania Wildlife Research Institute

PROCEEDINGS OF THE 14TH TAWIRI SCIENTIFIC CONFERENCE,

6th – 8th DECEMBER 2023

ARUSHA INTERNATIONAL CONFERENCE CENTRE, TANZANIA

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PROCEEDINGS OF THE 14TH TAWIRI SCIENTIFIC CONFERENCE

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ISBN .....

CONFERENCE THEME

"Human-Wildlife Coexistence for biodiversity conservation and socio-economic development".

MESSAGE FROM THE ORGANIZING COMMITTEE

The Tanzania Wildlife Research Institute (TAWIRI) scientific conferences are held biennially and brings aboard a wide range of stakeholders from within and outside the ountry. The Conference marks TAWIRI's 14th scientific conference under the Theme: "Human-Wildlife Coexistence for biodiversity conservation and socio-economic development". This theme was broken down into 10 sub-themes to enhance clarity and provide a better picture of the topics that were expected these included -

i. Human-Wildlife Interactions
ii. Emerging technologies for Wildlife Conservation
iii. Tourism Development and diversifications for social-economic development
iv. Wildlife Ecology and Ecological Interactions
v. Monitoring of Wildlife Population and threatened species
vi. Ecosystem Health and Wildlife Diseases
vii. Water Resources and Wetland Conservation
viii. Climate Change and - Ecological resilience
ix. Bee ecology, Beekeeping and Api-tourism development
x. Vegetation ecology, Invasive species and Habitat conservation

The conference was very successful and one of the most attended than the previous conferences. It brought together a total of 655 (an increase of 219 compared to the 13th Conference, representing 22 countries from allover the The conference brought key stakeholders from all levels, Government officials from the Ministry, Regional and district level, Policy Markers (Standing Parliament Committee for Land, Natural Resources and Tourism), TAWIRI Board, Board Chairpersons from sisterorganizations, Conservationists, Researchers, higher learning insitutions, Local Government Authorities Civil sociesty Development organizations, Media representative NGOs, CBCOs, and Private sectors

The presentations aimed at addressing the current wildlife management challenges and propose solutions and mitigations measure especially on issues related to increased Human-Wildlife Conflicts (HWC) resulting from population increased coupled with increased demand of land for cultivation, settlement and grazing; influx of livestock in protected areas as well as the impacts of climate change. Moreover, resolutions generated from this conference is hoped not only to improve wildlife resources in the country but also foster trade offs between sustainable utilization and long-term conservation while enhancing livelihoods through HWC mitigations.

We are also humbled to inform you that, TAWIRI managed to sponsor a total of 10 students who qualified to present their research finding during the conference. Of these 8 were from Sokoine University of Agriculture, 1 from IRA-UDSM and 1 from African College of Wildlife Management –Mweka, their levels of education ranged from First degree to post graduate , table bellow indicates their detals.

Table 3: Sponsored students during the 14th TAWIRI International Scientific conference

S/N	Name	University/College	Level
1	Ahamed Nyagongo	SUA	Postgraduate
2	Claus Augustino Thomas	SUA	Third Year -Degree
3	Omary Rajabu	SUA	BSc.
4	Glory Shayo	SUA	PhD Wildlife Ecol
5	Deusdedit Malulu,	IRA-UDSM	PhD
6	Grace Mchome	SUA	MSc-Second year
7	Upendo Richard	SUA	PhD Wildlife Ecol
8	Prisca Kahangwa	SUA	PhD Wildlife Ecol
9	Fredrick Msigwa	SUA	MSc ENAREC
10	Ndooto William	MWEKA	BSc.

On behalf of the Management and staff of TAWIRI, the Organizing Committee of the 14TH TAWIRI Scientific Conference is honored and pleased to invite all Scientists, Conservationists, Management authorities, Government Officials and representatives of NGOs and Civil Societies organizations higher learning institutions, and public at large to use the presented scientific results in this proceedings for better planning to ehance susstainanble conservation in the country.

Organizing Committee Members of the 14th TAWIRI International Conference of 2024

Dr. Julius Keyyu	Chairperson
CPA Harold Basinda	Vice Chairperson
Dr. Janemary Ntalwila	Secretary
Mwita Machoke	Member
Brian Maganga	Member
Rogastian Msafiri	Member

SPEECH OF THE DIRECTOR GENERAL, DR. EBLATE MJINGO, AT THE OFFICIAL OPENING OF THE 14TH TAWIRI INTERNATIONAL SCIENTIFIC CONFERENCE HELD AT THE ARUSHA INTERNATIONAL CONFERENCE CENTRE DECEMBER 6TH, 2023

Hon Angellah Kairuki (MP), Minister for Natural Resources and Tourism,
Hon Timotheo Mnzava (MP) Chairperson, Parliament Committee for Land, Natural Resources and Tourism,
Hon John Mongella, Regional Commissioner - Arusha,
Hon Dr. Peter Mathuki, Secretary-General of the EAC Member States,
Members of the TAWIRI Board of Directors,
Dr. Fortunata Msoffe, Acting Director of Wildlife,
Mr. Juma Kuji, Acting Conservation Commissioner, TANAPA,
Mr. Mabula Nyanda, Conservation Commissioner, TAWA,
Mr. Richard Kiiza, Conservation Commissioner, NCAA,
Prof. Dos Santos Silayo, Conservation Commissioner, TFS,
Excellencies and Head of Institutions,
Conference sponsors,
Conference Participants,
Distinguished Guests,
Ladies and Gentlemen.

On behalf of the TAWIRI Management and staff, I stand here to welcome you all to the 14th TAWIRI International Scientific Conference. I would like to thank Hon Angellah Kairuki (MP), Minister for Natural Resources and Tourism, for accepting our invitation to officiate this conference. We are thrilled to welcome all esteemed guests, scientists, conservation experts and participants to this momentous occasion.

Dear Participants: Today, TAWIRI marks a significant milestone in the wildlife sector as we converge to receive results of 249 wildlife research projects conducted in our country. Results will be presented in various forms, 162 oral presentations, 70 posters, 3 symposium, 2 seminars, one pre conference and one post conference.

The assembly is a unique forum where one can gain exclusive access to the outcomes of these studies through enlightening presentations, engaging symposiums, and insightful seminars. Together, we embark on a journey of knowledge-sharing and discourse, fostering a collaborative environment that propels our understanding of wildlife to new heights. We anticipate that the discussions and insights shared here will contribute to advancing and conserving our precious natural heritage. Thank you for joining us on this auspicious day as we collectively pave the way for a brighter future in the realm of wildlife research

Hon Minister: With these few remarks, I take great honour to welcome Dr. David Manyanza, Chairman of the TAWIRI Board of Directors, for his few remarks and to subsequently welcome your.

Thank you!

SPEECH OF THE CHAIRPERSON OF THE TAWIRI BOARD AT THE OFFICIAL OPENING OF THE 14TH TAWIRI SCIENTIFIC CONFERENCE HELD AT THE ARUSHA INTERNATIONAL CONFERENCE CENTRE (AICC), ARUSHA, DECEMBER 6TH, 2023

Hon Angellah Kairuki (MP), Minister for Natural Resources and Tourism,
Hon Timotheo Mnzava (MP) Chairperson, Parliament Committee for Land, Natural Resources and Tourism,
Hon John Mongella, Regional Commissioner – Arusha,
Hon Dr Peter Mathuki, Secretary-General of the EAC Member States,
Members of the TAWIRI Board,
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Excellencies and Head of Institutions,
Conference sponsors,
Conference Participants,
Distinguished Guests,
Ladies and Gentlemen.

First and foremost, I would like to thank **God** for making it possible for us to attend the 14th TAWIRI Scientific Conference, being held here at the Arusha International Conference Centre (AICC) in Arusha, commonly known to many as the Geneva of Africa.

Secondly, I would like to extend my heartfelt gratitude to Hon. Angellah Kairuki (MP), Minister for Natural Resources and Tourism, for graciously accepting the honour of officiating the opening ceremony of the 14th TAWIRI Scientific Conference, amidst your demanding schedule. Your presence symbolises the Government's unwavering dedication to the cause of wildlife conservation and research.

Hon Minister: This conference has brought together about 655 (an increase of 219 compared to the 13th Conference) from 22 countries. The list of participants include long-term wildlife research scientists from within and outside Tanzania. Please allow me to recognise all participants for their attendance at this conference.

Hon Minister: It is imperative to recognise that the oversight and administration of our protected areas fall under the Ministry of Natural Resources and Tourism and Management Authorities under the Ministry. However, for these authorities to effectively carry out the responsible stewardship of our natural resources, the utilisation of pertinent scientific information becomes paramount. In light of this reality, a compelling need arises for increased support for TAWIRI. This support is essential to ensure the ongoing generation of scientific data and insights that are pivotal in guiding our conservation efforts. It is with gratitude that we acknowledge the presence of these esteemed management authorities at this conference, for their involvement is fundamental to the continued success of our conservation initiatives.

Hon Minister: The TAWIRI Scientific Conferences are biennial gatherings designed to bring together wildlife researchers and conservationists from around the globe. These gatherings serve as a platform for exchanging knowledge and experiences in the domains of wildlife research and conservation. The inception and sustained organisation of these conferences serve as a testament to the significant importance that TAWIRI places on fulfilling its core mission. The research findings presented by wildlife researchers and conservationists on this platform serve as a vital avenue through which TAWIRI disseminates scientific information to the stakeholders tasked with safeguarding our invaluable wildlife resources.

Hon Minister: Those who have attended previous TAWIRI Conferences will recall that conference themes have been changing from one conference to the other in reflection of prevailing situations and needs in wildlife conservation. This year's theme is ***"Human-Wildlife Co-existence for Biodiversity Conservation and Socio-Economic Development*".** This theme reflects our commitment to harmonising the needs of our people and the conservation of our invaluable wildlife. Indeed, the relationship between communities and wildlife is at the core of our collective well-being and economic prosperity.

Hon Minister:

TAWIRI is mandated to undertake, coordinate and supervise wildlife research that contributes to the conservation and sustainable management of Tanzania's diverse and unique biodiversity resources. Our work has been instrumental in preserving the rich tapestry of species that call our country home. Wildlife is not just a source of pride and beauty but also essential for maintaining the balance of our ecosystems and providing vital services such as pollination and carbon sequestration. Furthermore, wildlife conservation directly supports local communities through tourism and sustainable resource management. Over the years, TAWIRI has championed wildlife research and dissemination of findings.

Hon Minister: Our journey from the first scientific conferences started in 2000 with about 60 participants and 15 presentations. The number of participants has increased over the years to more than 600 and over 250 presentations during this Conference. This signifies the recognition of the importance of wildlife research within our nation. More significantly, our impact has extended beyond our borders, influencing other countries in the region to emulate. This indicates that TAWIRI's conferences have had a substantial regional, continental and global impact as this time round for the first time ever we have participants from Congo DRC, Zimbabwe, China, Myanmar and Singapore. We take pride in the fact that our work has benefited Tanzania and has been a source of inspiration for our neighbouring countries in the region.

Hon Minister: The dissemination of research findings is a linchpin of TAWIRI's mission. It is the process by which we share the knowledge gained through research with the world, contributing to the advancement of science and the conservation of our natural heritage. The significance of this process cannot be overstated. By sharing research findings, we provide the scientific information necessary for wildlife managers to make informed decisions. It serves as a guidepost for conservation policies, ensuring they are rooted in scientific evidence and practicality. Moreover, the dissemination of research findings is essential for long-term species monitoring, aiding us in understanding population dynamics, threats, and potential interventions.

Hon Minister: In this conference, we have 3 keynote papers, 3 symposia, 2 seminars and 12 parallel sessions summing up 232 presentations of which 162 are oral and 70 posters. Full manuscripts will be submitted to TAWIRI for review, and those that qualify will be published in the 14th TAWIRI Scientific Conference Proceedings. If used properly, I believe these findings will contribute significantly to sustainable wildlife conservation in the country and the world at large.

Hon Minister: TAWIRI collaborates closely with other researchers from within and outside the country to generate meaningful and useful information for conserving wildlife resources. This is witnessed through the number of projects that the Institute registered during the financial year 2022/2023, where a total of **201** projects and **451** research scientists were registered and supervised. I am pleased to inform you that the number of Tanzanian wildlife researchers increased from 7% in 1994/95 to 63% in 2022/23. Further, as a strategy for enhancing the capacity to carry out wildlife research, the Institute has continued to establish collaborations with local and international institutions.

Hon Minister: While we celebrate our accomplishments, we must also address the challenges we face. Currently, the Institute has no Head Office building after the former building was demolished due to structural problems and some of the staff have been relocated. Also, other buildings at the Research Centres require major repairs.

Furthermore, the Institute has inadequate working gear such as cars and research equipment. Without proper facilities and resources, our ability to conduct meaningful research and extend our influence is hindered. Funding for strategic research is another issue. It is a fact that most of our funds are donor-dependent. While donor support has been invaluable, it can sometimes lead to a misalignment of priorities, as external donors may have distinct interests that may not always align with the national conservation agenda. To overcome these challenges, we need to find a sustainable source of funding that allows us to set our research priorities based on the country's needs.

Hon Minister: In light of these challenges, we seek the Government's efforts in establishing a research fund to help in this regard. We suggest financing this fund through a one-dollar contribution from each tourist entering our country. This contribution, dedicated to supporting strategic research, infrastructure development, and wildlife conservation, will be an investment in the future of our wildlife and the well-being of our nation. If implemented, this initiative will not only reduce our reliance on external donors but also ensure that our research priorities remain firmly aligned with our national conservation goals.

Hon Minister: Organising TAWIRI Biennual Scientific Conference requires significant resources. Many donors and collaborating Institutions have been supporting and sponsoring TAWIRI Scientific Conferences. We have four categories, golden, Silver, Bronze and general sponsors. With time limit, I humbly request you, Honourable Minister, to offer appreciation awards to our golden conference sponsors. They include Ministry of Natural Resource and Tourism (MNRT), USAID- Tuhifadhi Maliasili Project, UAG Group, Otello Business Company (OBC), Tanzania People and Wildlife (TPW), World Wide Fund for Nature (WWF), Tanzania Tourist Board (TTB) and National Microfinance Bank (NMB). We also thank other sponsors for their support and will be given the awards during the networking dinner in the evening.

Hon Minister: With these few remarks, I now have the great honour to welcome the Honorable Minister to address this congregation and officiate the opening of the 14th TAWIRI Scientific Conference.

THANK YOU!

AHSANTE

SPEECH OF THE MINISTER FOR NATURAL RESOURCES AND TOURISM HON ANGELAH KAIRUKI (MP) PRESENTED AT THE OFFICIAL OPENING OF THE 14TH TAWIRI INTERNATIONAL SCIENTIFIC CONFERENCE, HELD AT THE ARUSHA INTERNATIONAL CONFERENCE CENTRE (AICC), ARUSHA ON DECEMBER 6TH, 2023

Dr. Hassan Abbas, Permanent Secretary, MNRT,
Hon Timotheo Mnzava (MP) Chairperson, Parliament Committee for Land, Natural Resources and Tourism,
Hon John Mongella, Regional Commissioner – Arusha,
Hon Dr. Peter Mathuki, Secretary-General of the EAC Member States,
Dr. David Manyanza, Chairperson of the TAWIRI Board,
Members of the TAWIRI Board,
Dr. Fortunata Msoffe, Acting Director of Wildlife,
Dr. Eblate Mjingo, TAWIRI Director General, and the Management of TAWIRI,
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Mabula Nyanda, Conservation Commissioner, TAWA,
Richard Kiiza, Conservation Commissioner, NCAA,
Prof. Dos Santos Silayo, Conservation Commissioner, TFS,
Excellencies and Head of Institutions,
Conference Sponsors,
Conference Participants,
Distinguished Guests,
Members of the Press,
Ladies and Gentlemen.

Good Morning!

Distinguished conference participants, Ladies and gentlemen,

First and foremost, I would like to thank the **Almighty God** for making this gathering possible and I am glad that you are all here today and also recognise participating virtually.

Let me take this opportunity to express my sincere gratitude to the Ministry of Natural Resources and Tourism, Board and Management of the Tanzania Wildlife Research Institute (TAWIRI) for inviting me to officiate the 14th TAWIRI International Scientific Conference here in Arusha, I feel greatly honoured.

Distinguished conference participants, Ladies and gentlemen,

I am aware that Tanzania is among the four mega-biodiversity Nations in the world hosting an extraordinary array of flora and fauna. The country is one of the few countries harbouring over 20% of Africa's impressive large mammal population. Wildlife viewing is the leading tourist attraction in Tanzania, contributing to 21% of the GDP and 25% of foreign exchange earnings and more than 1.6 million direct and indirect employments per year. Because of socioeconomic importance of wildlife, the country has set about 32.5% of its land for wildlife conservation in terms of 21 National Parks, 32 Game Reserves, 23 Game Controlled Areas, 3 wetlands (RAMSAR Sites) and 28 Wildlife Management Areas. For sustainable conservation of our wildlife resources, it is imperative that conservation and management must rely on research findings to guide informed decisions.

Distinguished conference participants, Ladies and Gentlemen,

TAWIRI as a Government Institution has been at the forefront since its establishment in 1980 to conduct, coordinate and provide scientific advice to the government, management authorities and the general public regarding sustainable conservation and tourism development in the country. We can all agree that research without dissemination is of no use and one way of TAWIRI to reach a wider audience has been via TAWIRI Scientific Conferences. This has been proven to be true and we are all here for the 14th conference to be organized by TAWIRI since the year 2000.

Distinguished conference participants, Ladies and Gentlemen,

The importance of TAWIRI as a strategic institute in the generation of knowledge for the promotion of conservation and tourism cannot be overemphasized. The first President of Tanzania, Mwalimu Julius K. Nyerere in September 1961, at a symposium on the Conservation of Nature and Natural Resources, gave a speech that has become known as the '*Arusha Manifesto*'. The statement resonates across most of Africa today: Among others, He said, I quote,

> "*The conservation of wildlife and wild places calls for **specialist knowledge, trained manpower, and money**, and we look to other nations to cooperate with us in this important task – the success or failure of which not only affects the continent of Africa but the rest of the world as well*".

Therefore, the Government will continue to set adequate funds to the institute for training researchers and staff so as to create a critical mass of the next generation of competent Tanzanians with specialized knowledge in wildlife research including emerging conservation technologies.

Distinguished conference participants, Ladies and Gentlemen,

In line with the Mwalimu Julius K. Nyerere Manifesto, the government understands the linkage of research and innovation for national development. This can be witnessed in the National Five-Year Development Plan III 2021/22 - 2025/26, the Tanzania Development Vision 2025 and the ruling Party Election Manifesto (2020-2025) on ensuring that research and innovation create avenues for rapid socio-economic development. Furthermore, due to the importance of biodiversity conservation, the Government has ratified several international conventions including the Convention on International Trade in Endangered Species of Wild Flora and Fauna

(CITES), the Convention on Biological Diversity (CBD), the World Heritage Convention, and Ramsar convention as well as regional conventions/ treaties including the East African Treaty (Article 114 on Tourism and Article 115 on wildlife management).

Distinguished conference participants, Ladies and Gentlemen,

I am informed that the theme of this conference is "***Human-Wildlife Co-existence for Biodiversity Conservation and Socio-economic Development"***. We understand that the complex relationship between humans and wildlife has been there for many years. This interaction has implications for our socio-economic development, environmental sustainability, and the overall well-being of our planet. Therefore, this conference theme is timely, especially in Tanzania where human-wildlife interactions have increased due to human activities, especially settlement, agriculture and livestock grazing, inadequate land use plans near protected areas, climate change, blockage of wildlife corridors, and invasion of alien species and change of wildlife behaviour.

While most efforts have been directed towards the development of mitigation measures, fostering wildlife-human co-existence might be a turning point towards addressing human-wildlife conflicts in Tanzania in order to enhance socio-economic development. In addition, technology and innovation have a significant role to play in our pursuit of coexistence. Advancements in wildlife monitoring, tracking, and sustainable resource management have the potential to transform how we protect and coexist with the natural world. By harnessing the power of science and technology, we can create win-win solutions for both humans and wildlife.

All this can be made possible through research and I acknowledge how TAWIRI has been at the frontline actively ensuring conflicts are minimized all over the country through on-site training, monitoring movements and in some cases driving wildlife back to Protected Areas.

Distinguished conference participants, Ladies and Gentlemen,

It has been mentioned that TAWIRI currently has no building for the Head Office after the former building was demolished and some of the staff have been relocated. Also, it has been mentioned that other buildings at the Research Centres require major repairs. In order to bring image change to the institute and enable the institute to achieve its establishment objective, the Government will set aside special funds for the construction of a Head Office building, renovation of buildings at the research centres as well as procurement of research and laboratory equipment.

Distinguished conference participants, Ladies and Gentlemen,

I also heard that another pertinent challenge of the institute is limited funds for conducting strategic and demand-driven projects to address sectoral challenges and the promotion of tourism. It is known that most leading tourist destinations including Serengeti National Park and Ngorngoro Conservation Area are a result of research information. We all understand the commitment of the Sixth Government of Tanzania to promote tourism, as evidenced by the recent initiative by the President of the United Republic of Tanzania, Her Excellency Dr. Samia

Suluhu Hassan through the information generated and attractions shown by the Film titled 'TANZANIA: THE ROYAL TOUR'. From this initiative, the number of tourists has continued to increase from 1,711,625 in 2021 to 3,818,180 in 2022, which is an increase of 123% and it is anticipated to reach 5 million in 2025 as per the ruling Party Manifesto.

Distinguished conference participants, Ladies and Gentlemen,

As I have said, it is information generated from research that made the Northern tourist circuit in Tanzania famous in terms of tourist destinations and now the move is to the Southern Circuit. To realize this, the Government requires TAWIRI to conduct research and target the Southern circuit for tourism promotion in terms of tourism information, attractions, hospitality, visitor satisfaction and views. The Government commits to increase funding to the institute to enable you to conduct strategic research projetcs for conservation and toruism promotion. As a permanent solution of funding research.

Distinguished conference participants, Ladies and Gentlemen,

While I commend scientists for their contribution towards wildlife conservation and tourism promotion through the generation of scientific knowledge, let me take this opportunity to pose a couple of challenges. First, are the increasing human-wildlife conflicts in recent years some of which are associated with crop damages, human injuries or death, property damages, livestock depredation, and retaliatory killings of keystone species such as elephants and lions. Research data from TAWIRI has shown that a total of 53 Districts out of 91 Districts in Tanzania Mainland are leading in human-wildlife conflicts especially crop raiding by elephants. Due to this, the Government is committed to enhancing co-existence, I am happy that the Ministry of Natural Resources and Tourism has prepared and submitted an '*Emergency and mid-term strategy to mitigate Human-Wildlife Conflicts in Tanzania*'. Therefore, the Government will be looking forward to receiving recommendations on how best we can reduce human-wildlife conflicts and foster human-wildlife coexistence in the country. Other challenges include loss of wildlife habitat, blockage of wildlife corridors, invasive alien plants, wildlife diseases, and declining wildlife populations in some areas. These are a threat to wildlife conservation and tourism. In these regards, research should be directed to also address these challenges for informed management decisions.

Distinguished conference participants, Ladies and Gentlemen,

Among the top drivers of human-wildlife conflicts is blockage of wildlife corridors. I have been informed that the country has 61 wildlife corridors to facilitate movement of wildlife from one habitat to another. However, 41 of the corridors have been blocked, and the remaining 20 need immediate restoration in order to reduce human-wildlife conflicts. I am also aware that the Ministry developed a 'Tanzania Wildlife corridors assessment, prioritization and action plan of 2023-2027'. The Government calls upon all stakeholders to implement this action plan as well as more research on status, threats and restoration of wildlife corridors in Tanzania.

Distinguished 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 the contribution of the Ministry of Natural Resources and Tourism (MNRT) through the Wildlife Division, USAID-Tuhifadhi Maliasili, United Asian Group (UAG), Otello Business Company (OBC), Tanzania People and Wildlife (TPW), WWF - Tanzania, National Microfinance Bank (NMB), Tanzania Tourist Board (TTB), The Nature Conservancy (TNC), Tanzania National Parks (TANAPA), Gadgetronix, Jane Goodall Institute (JGI), Ngorongoro Conservation Area Authority (NCAA), Tanzania Wildlife Management Authority (TAWA), Tanzania Commission for Science and Technology (COSTECH), Grumeti Fund, Tanzania Forestry Services (TFS), Agakhan University, Tanzania Forestry Research Institute (TAFORI), Frankfurt Zoological Society (FZS), REGROW project, Oikos East Africa, College of African Wildlife Management – Mweka, the Arusha International Conference Centre (AICC), Gran Melia Hotels, Mount Meru Hotel, Tanzania Tour Operators (TATO), Tanzania Elephant Foundation (TEF), Kenzan Wildlife Safari Limited, Wildlife Conservation Society (WCS), Tanzania Engineering and Manufacturing and Design Organisation (TEMDO) and African Queen Safari.

Allow me also to thank the Organizing Committee of the 14th International TAWIRI Scientific Conference, for working tirelessly and making the event very successful.

Distinguished conference participants, Ladies and Gentlemen,

Let me conclude my remarks by wishing all participants a fruitful scientific conference and deliberations. For participants coming from outside Tanzania, I would once again like to welcome you to "Tanzania, the Land of Serengeti, Kilimanjaro, Ngorongoro Crater and Zanzibar for your 'Untamed and Unforgettable Experience'.

I urge you to spare a few days after the conference to visit some of these fascinating tourist attractions in the country, especially Serengeti National Park, which has been voted the best national or safari park in Africa for five consecutive years. And also Ngorongoro Conservation Area, that has been voted Africa Leading Tourist attraction this year. Indeed, you will find a home away from your home.

With these remarks, I now declare that the 14th TAWIRI International Scientific Conference is officially opened.

THANK YOU!

RESOLUTIONS FOR THE 14TH TAWIRI INTERNATIONAL SCIENTIFIC CONFERENCE, HELD ON 6TH – 8TH DECEMBER 2023, AT THE ARUSHA INTERNATIONAL CONFERENCE CENTRE

The conference resolution contained thoughtful ideas and opinions, and recommendations on how to improve the conservation sector in Tanzania were provided so that to enhance sustainable development of our future biodiversity for enhancing livelihoods especially now when the sector is facing a big challenge of Human –Wildlife Conflicts. Main issues that were raisied are:-

Participants views

They were aware of the Government commitment on conservation of biodiversity resources as an integral components of sustainable economic growth the robust quality of scientific research that serves as a valuable asset in securing a sustainable future for biodiversity conservation, tourism and livelihoods. The responsibility of TAWIRI and its biannual conference is to formulate recommendations on conservation priorities, strategies, and anticipated benefits for biodiversity. Is worth noting that;

i. The well-being of humans is intricately linked to the health of ecosystems resulting in degradation of natural resources
ii. The impacts of human-driven climate change are marked by growing climatic extremes, increased variability in rainfall, and the potential for significant rainfalls with adverse effects on food production
iii. The importance of setting aside 32.5% of the country's land as protected areas and their effective management for Tanzania's nature-based economic growth
iv. Acknowledging the escalating degradation within protected areas due to unsustainable levels of illegal activities such as grazing, logging, bushmeat consumption, retaliatory killings, and invasive species
v. Recommending stronger reinforcement of regulations and adherence to laws to prevent illegal offtake of natural resources and further habitat degradation.

Key Issues to Conservation

Human-Wildlife Coexistence:

i. Human Wildlife Coexistence is rapidly breaking down due to unsustainable anthropogenic activities and insufficient implementation of laws and regulations
ii. Need for novel solutions to retain zones where people and wildlife can coexist, preserving key ecosystem services, including tourism benefits
iii. Need for substantial interventions to maintain soft borders, emphasizing the fair and transparent distribution of benefits and costs.

Corridor Protection and Landscape-Level Connectivity:

Urging the implementation of effective corridors to ensure connectivity of the protected areas to ensure viability of wildlife populations.

Sustainable Wildlife Tourism:

i. Urgently evaluating and increasing research efforts in the spatial zoning of wildlife tourism infrastructure, with a focus on highly visited areas such as Serengeti NP, Ngorongoro CA, and Kilimanjaro NP
ii. Diversification of tourism products within andoutside protected areas, for the long-term growth of the tourism industry

Integrated National Cross-Sectoral Strategy:

i. Recommending the development of an integrated national cross-sectoral strategy for sustainable land use (zoning, corridors)
ii. Ensuring the implementation of cross-sectorial strategy in high-priority areas that experience rapid losses
iii. The conference called upon all stakeholders to actively collaborate in implementing these recommendations for the coexistence of humans and wildlife, ensuring the long-term sustainability of Tanzania's biodiversity and socio-economic development

5.2.5 Key recommendation

i. Explore ways in which communities can benefit economically from wildlife conservation, such as through responsible tourism, sustainable resource management, or other wildlife-related enterprises
ii. Ensure land use planning and zonation
iii. Ensure sustainable development by promoting development practices that consider long-term ecological sustainability
iv. Recognize the need for inter-ministerial approaches to ensure the sustainability of the PAs (livestock, mining, agriculture, forestry, water)
v. Mitigate Human-Wildlife Conflict by finding ways to minimize these conflicts for both human safety and the well-being of wildlife
vi. Engage local communities in conservation efforts and sustainable development initiatives, recognizing their role as stewards of the environment and key partners in achieving coexistence
vii. Enhance Gender mainstreaming in Climate Change adaptation policies, and frameworks
viii. Encourage the establishment of Community Conservation Banking (COCOBA)
Diversification of tourist's attractions by engaging local community and public sector income-related activities (i.e. viticulture, avitourism, api-tourism) is important for the tourism industry and socio-economic development in Tanzania
ix. Engage multi-sectoral (wildlife, veterinary and public health) disease prevention approaches/strategies is crucial in the face of human population growth and climate change
x. Maximizing the potential of technological innovations (tool and methodology) in wildlife research, from planning, data acquisition and efficient data management

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Organizing a Conference needs support, collaboration and participations from all stakeholders. TAWIRI acknowledges all delegates; majority being researchers, academicians and conservationists who attended the conference in particular those who prepared presentations that enriched the conference with valuable conservation information.

Special thanks goes to the Conference Organizing Committee who worked tirelessly to make the event possible.

We also express our sincere thanks to all conservation authorities, institutions, organizations and private companies for both material and financial support that made the Conference successful. These organizations are not only our recurrent supporters to this particular event, but also support a wide array of conservation and research activities in the country. In the 14th TAWIRI International Scientific Conference, we sincerely thank the organizations (whose logos are shown below) and urge them to please keep up the spirit!

Sponsors of the 14th TAWIRI International Scientific Conference held form 6th – 8th December 2023.

KEYNOTE SPEAKERS

We are very gratefull to the Key note speakers who prepared the plenary papers and delivered key messages during the conference. Three plenary papers were presented, each had special message that was linked to the main Conference Theme. Pleanry presentations are, key papers that provides general overview of the chosen topic that need to be adrresed and which conservation driven issues. Details of the key papers and speakers are presented in the table bellow

Dr. Julius Keyyu

Topic: Wildlife corridors: Status, threat and implication sustainable biodiversity conservation and community livelihood in Tanzania

Dr. Keyyu is a Chief Research Officer and the Director of Research Development and Coordination at the Tanzania Wildlife Research Institute (TAWIRI) since 2006. Has 25 years of research experience on ecosystem and population health especially wildlife disease ecology. His research work has mainly been on ecological interactions at the human-livestock-wildlife interface using a One health approach on viral, bacterial, parasitic and zoonotic diseases. Other areas of research engagement include biodiversity conservation, biodiversity and socio-economic surveys, Environmental and Social-Impact Assessment (ESIA), wildlife habitats connectivity especially corridors and population genetics. Has contributed to knowledge, science, technology and innovation through 80 papers in peer reviewed journals including 3 papers in the journal of Science, and currently 3 registered patents (two on hair loss prevention/ hair growth promotion and one on skin lightening/wrinkle improvement).

Key Message

Wildlife corridors have major ecological values in protected areas as well as for biodiversity conservation and community livelihood. In order to show its commitment to maintain and restore wildlife corridors, the Tanzanian Government passed the Wildlife Conservation (Wildlife Corridors, Dispersal Areas, Buffer Zones, and Migratory Routes) Regulations 2018 (known as "Corridor Regulations"). In 2022, Tanzania produced a Tanzania wildlife corridor assessment, prioritization and action plan for 2022-2026, where a total of 61 corridors were identified. In the assessment report, 41 of these corridors were threated of which 20 were prioritized for conservation or restoration.

Many wildlife corridors are at a cross road and the country will soon lose many due to a number of threats including agriculture, human settlement, livestock grazing, and logging/ charcoal making. In many wildlife corridors, land use land cover maps have shown that agriculture, bare land and shrubland are increasing while woodland, grasslands and water are decreasing, an indication of loss of habitat quality. It is concluded that the future of wildlife corridors in Tanzania is black and prevention of their loss is a fundamental action; if we will continue with business as usual, most of wildlife corridors will disappear; the ongoing threats and loss of corridors is a wakeup call, that Nature is calling to abet habitat and biodiversity loss. More importantly, it is high time to solve the fundamental issue, that is to conserve and open the corridors by all means, the rest are just temporal measures

Prof. Wineaster Anderson

Topic: Innovation and Technology for Conservation and Sustainable Tourism development

Prof. Wineaster Anderson (PhD) is the Deputy Vice Chancellor of the University of Dodoma responsible for Planning, Finance and Administration. Is a Professor of Marketing She was formerly a Dean of University of Dar es Salaam Business School and Director of Quality Assurance for the University of Dar es Salaam. She holds PhD (2008) and Masters (2005) in Tourism and Environmental Economics as well as MBA (2001) and Bachelor of Commerce (1999) in Marketing. Prof. Anderson has researched and published widely in the areas of international business, sustainable tourism, economics and marketing of tourism, poverty alleviation and gender.

Key Message

The paper introduced an innovation and technology approach as among the key drivers for managing conservation and sustainable tourism in tourist developing destinations with particular interest on Tanzania. The choice of the country is based on its comparative advantage that rests on its natural assets. Tanzania has the highest percentage worldwide (about 32.5%) of its land in a protected natural state, compared to the world average of 4%. Over 307,800 square kilometers of its land is protected in the form of national parks, game reserves, forests, beaches and archeological sites and so forth. The presentation answers the key question "Why innovation and technology in managing conservation and sustainable tourism development? It derives the meaning of sustainable tourism from the economic, social and environmental impacts; and provides empirical evidences of innovation in tourism focusing on product, process, managerial, marketing and institutional perspectives. Major trends in technologies shaping the future of conservation and sustainable tourism development including artificial intelligence, internet of things and digital tourism have been highlighted. The presentation concludes by providing practical implications for policy making and managerial decisions.

Prof. Veldhuis, M. Paul

Topic: Human-wildlife coexistence: biodiversity as the basis for a sustainable future

Is an Assistant Professor on fundamental principles in the organization of ecosystems at the Institute of Environmental Sciences, Leiden University, NL. Has a long working experience in savannah ecosystems in southern and eastern Africa for over 10 years enabling him to obtain the basis for understanding the complex interactions that shape savannah ecosystems. The innovative character made him to be recognized by the Royal Dutch Academy of Sciences (KNAW), but also by Leiden Science Faculty (Discoverer of The Year award 2020) and the British Ecological Society (Harper Prize 2014 for best paper by an early career). Has managed a number of international projects and published several paper in higher impacts journals including Science Journal

Key Message

Biodiversity is the basis of sustainable development, Tanzania is doing incredibly well with respect to biodiversity conservation however Human-wildlife conflict is increasing and possing threat to conservation. Pointed out Key conservation opportunities that lies in rural areas, by enabling communities to restore healthy landscapes and reduce human-wildlife conflict

Restoring soft-boundary design by a mosaic of PA status will lead to increased biodiversity and reduce human-wildlife conflict

Towards sustainable co-existence interdisciplinary, intersectroal and international collabotion is needed.

Treatment response of Giraffe Skin Disease (GSD) to Antibiotic, Ivermectin, and Antibiotic-Ivermectin combination in Ruaha National Park

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ABSTRACT

Giraffe Skin Disease (GSD) is an infectious disease that was first recorded in the northern section of Ruaha National Park at Lunda area in Tanzania in 2000. To date, the causative agent and treatment for GSD is not yet known despite the fact that a number of studies have been conducted. This treatment trial was conducted to determine the efficacy of ivermectin, antibiotic and their combination to control Giraffe Skin Disease (GSD) in giraffes in Ruaha National Park from October 2022 to February 2023. A total of 18 giraffes were immobilized using 20mg Etorphine HCL (M99) each and reversed with Diprenorphine (M5050) at 3 times the dose of M99. The immobilized giraffes were treated as follows; 5 giraffes were treated with long acting 20% Oxytetracycline injectable solution (Alamycin LA 300, Norbrook Laboratories Ltd, Northern Ireland, UK) at a dose of 20mg/kg; 3 giraffes were treated with 1% w/v ivermectin injection per subcutaneous route (Bimectin, BIMEDA AMEA Ltd, Dublin, Ireland) at a dose of 200mcg/kg, equivalent to 1ml/50kg); 6 giraffes were treated with a combination of 20% long-acting antibiotic and 1% ivermectin, 4 giraffes were left as untreated control (2 negative control and 2 positive control). All immobilized giraffes were fitted with Savanna tracking GPS collars on the tail and ear tags with numbers to enable tracing of giraffes for assessment of treatment efficacy. Results on the efficacy of drugs against GSD three months after treatment showed that 50% of giraffes treated with ivermectin alone had high significant recovery while 50% had moderate improvement; 50% of giraffes treated with antibiotic alone had significant recovery while 50% had moderate recovery, and that 66.66% of giraffes treated with a combination of ivermectin and antibiotic had significant recovery while 33.33% had moderate improvement. One of the two un-infected control giraffes in an infected herd with collar number 4044 and ear tag 2555 was infected with GSD three months after commencement of the study. Based on data collected, it was concluded that GSD responds well to treatment with ivermectin and antibiotic combination or ivermectin alone, and that the efficacy of drugs was high for fresh cases than in chronic cases. To overcome challenges of finding treated giraffes for assessment and costs of repeated giraffe immobilizations, a controlled treatment trial using giraffes kept in an animal capture facility (boma or kraal) is recommended, repeated drug treatments is also recommended to improve drug efficacy.

Key words: Giraffe Skin Disease, GSD, Giraffe, Ruaha,

INTRODUCTION

The giraffe is the world's tallest living terrestrial animal, an African ikon and it is well known for its spotted pelage patterns, long legs, long neck and its habit of browsing vegetation from high branches. The Giraffe is a National animal in Tanzania and is used on football teams, bank names, bank notes, passport pages, and drinks. Giraffes inhabit large ranges in semi-arid subtropical savannah habitats varying from open to closed woodlands and dense shrubby thickets (Furstenburg, 2013; Muller et al., 2016). Giraffe are browsers and spend most day light hours feeding on a variety of trees and shrubs, leaves, stems, flowers, and fruits (Pellew, 1984). The international Union for Conservation of nature (IUCN) currently recognizes giraffes as a single species (*Giraffa camelopardalis*) with nine sub-species distributed across sub-saharan Africa (Muller, et al., 2016); whereby the Masai giraffe (*Giraffa tilppelskirchi*) is the sub-specie found in Tanzania.

History indicates that giraffe occurred throughout sub-saharan Africa in open savannah, scrublands and dry forests (Muller et al., 2016). Recent studies have identified dramatic declines in many giraffe populations, and that the current total number of giraffes across Africa has plunged by approximately 38% in the past 30 years, from about 157,000 in 1985 to about 97,500 in 2015 (Muller et al., 2016). Giraffe are still widely distributed in northern and central Tanzania. Since 1986 TAWIRI has conducted Systematic Reconnaissance Flight (SRF) field surveys for giraffe approximately every three years in Tanzania's major national parks and ecosystems. The total giraffe population estimate in Tanzania in 2002 was 33,389±4,887; and that in 2014, the total giraffe population in the country was estimated at 26,079 ±2,772 individuals (TAWIRI, 2014; unpublished report). Long term population trend in Tanzania has shown that the giraffe population is increasing in West Kilimanjaro-Lake Natron ecosystem, Katavi-Rukwa ecosystem and Tarangire-Manyara ecosystem. On the other hand, giraffe population estimates have shown a stable trend in the Serengeti ecosystem, Saadani National Park and Selous-Mikumi ecosystem. However, the giraffe population estimates have shown a decreasing trend in Mkomazi National Park, Moyowosi-Kigosi ecosystem and Ruaha-Rungwa ecosystem.

Although giraffes are still widespread in northern and central Tanzania, according to the National giraffe conservation plan of 2020-2024, giraffes are threatened by habitat loss and fragmentation, hunting and diseases; which are a major cause of population decline (Hofberg et al. 2017; Bolger et al. 2019). A recent summary of relevant research in the country draws the following conclusions (Muneza et al. 2017): (i) giraffe populations in Tanzania have been declining for the past 30 years, and (ii) if the rate of decline and major threats to giraffe are not reversed, there is a high risk of losing the last strongholds of giraffe in Tanzania.

Diseases are among the drivers of species local extinction; population decline and reduced visitor satisfaction in various ecosystems in Tanzania and globally. The current main diseases affecting giraffes in Tanzania are Giraffe Skin Disease (GSD) and Giraffe Ear Disease (GED). Giraffe Skin Disease (GSD) is highly prevalent in Ruaha National Park (RUNAPA) and has currently been recorded in Tarangire, Lake-Manyara and Serengeti National Parks in Tanzania. The risk of wildlife population decline due to diseases has been increasing over time due to human population growth, human-livestock-wildlife interaction as a result of human activities in protected areas and grazing in protected areas. Human-livestock-wildlife interaction has resulted into infectious disease pathogens crossing the species-specific barrier. Giraffe skin giraffe disease has been spreading over time in Maasai giraffe in RUNAPA since its first occurrence in late 2000's.

Giraffe Skin Disease (GSD) is an emerging disease of free ranging giraffe recognized in the last 25 years in several species (Han et al., 2022), affecting populations in Tanzania, Uganda, Kenya, South Africa, Namibia, Botswana and Zimbvabwe (Epaphras et al., 2012; Kalema, 1996; Lee and Bond, 2016; Lyaruu, 2010; Mpanduji et al., 2011; Muneza et al., 2016; Whittier et al., 2020). However, characteristics of GSD vary by region and giraffe species (Han et al., 2022). In Tanzania, GSD was first recorded in the northern section of the Ruaha National Park at Lunda area in 2000, thought it appears that the disease had been present for some time (Muse et al., 2012), but was being missed due to inadequate surveillance system. Previous epidemiological studies have indicated that the prevalence is low during the dry season (63%) and high during the wet season (82%), and that risk factors for infection and transmission are less known. The previous recorded prevalence of GSD in RUNAPA was 79.8% and that all areas of the Park were affected (Muse et al., 2012), this is a very high prevalence for a keystone specie. The disease appears to affect mostly the fore limbs (98.6%) and that despite the diversity and proximity of giraffes to other wildlife the disease is exclusive to giraffes (Muse et al., 2012). Globally, since 2016 giraffes have been moved from Least Concern (LC) to Vulnerable (VU) in the IUCN red list. The most causes of giraffe population decline include habitat loss, poaching, diseases and climate change associated impacts, among others. GSD lesions in affected Masai giraffe in Tanzania appears have been described by Muse et al., (2012), and appears to be different from GSD lesions in other giraffe sub-species, in terms of gross appearance and location of lesions. In spite the fact that GSD has been recorded in Tanzania since 2000; the primary or exact aetiology of GSD, pathogenesis, long-term impact and fate of infected giraffes in Tanzania is not known. Previous studies conducted in RNP isolated multiple agents including nematodes, fungi and bacteria (Mpanduji et al., 2011), but the nematode could not be identified to species level. Most importantly, it is not yet known what drugs can be used for treatment of GSD in order to safeguard giraffe health and welfare. Therefore, this study was conducted to determine drugs that can be used for treatment of GSD as well as determine the fate of infected giraffes in Ruaha National Park.

MATERIALS AND METHODS

Study design

This was study was a longitudinal descriptive analytical clinical field conducted to determine the effectives of various drugs in the treatment or control of Giraffe Skin disease as well as the fate of infected giraffes.

Study area

The study will be conducted in Ruaha National Park (RNP) which is located in Iringa region, Southern highlands of Tanzania. The park is geographically situated between latitudes 7°30'S and 8°00'S and longitudes 33°50'E and 35°25'E. It is the only park in the country with flora and fauna characteristic of the dry East African savannah and the Southern African (Zambezian) miombo woodland. The park has species associated with the unique wildlife habitat represented by *Acacia, Combretum, Commiphora and Brachystegia* (miombo) woodland and perennial grasses. The wildlife species in RNP include the rare Greater and lesser Kudu, the roan and sable antelope.

Treatment trial of infected giraffes

Giraffes were searched using ground transects, and upon sighting a giraffe herd, all giraffes in the herd were inspected for lesions of GSD using a binocular and a high-resolution digital camera. Infected giraffes were scored for the severity of lesions (low, medium, high) and one or two giraffes were selected for immobilization and treatment; a balance of severity of lesions and number of individuals was strived to be reached in each group and drug. A total of 18 giraffes were immobilized using 20mg Etorphine HCL (M99) each and reversed with Diprenorphine (M5050) at 3 times the dose of M99. The immobilized giraffes were treated as follows; 5 giraffes were treated with long acting 20% Oxytetracycline injectable solution (Alamycin LA 300, Norbrook Laboratories Ltd, Northern Ireland, UK) at a dose of 20mg/kg; 3 giraffes were treated with 1% w/v ivermectin injection per subcutaneous (Bimectin, BIMEDA AMEA Ltd, Dublin, Ireland) at a dose of 200mcg/kg, equivalent to 1ml/50kg); 6 giraffes were treated with a combination of 20% long-acting antibiotic and 1% ivermectin, 4 giraffes were left as untreated control (2 negative control and 2 positive control). All immobilized animals were fitted with Savanna tracking GPS collars on the tail and ear tags with numbers to enable tracing of giraffes for assessment of treatment efficacy. The giraffe identification (collar/ tag), sex, collaring location/ park area and part of the body affected for giraffes in the treatment trial are shown in Table 1.

SN	EAR TAG NUMBER	GPS COLLAR NUMBER	COLLARING PARK AREA	SEX	AGE	PART OF THE BODY AFFECTED
1	2545	4063	Mwangusi	Female	Adult	Fore legs
2	2542	4059	Makutano	Male	Adult	Fore legs
3	2543	6055	Serengeti ndogo	Female	Adult	Fore legs
4	2546	4057	Lunda	Female	Adult	Fore legs
5	2544	4054	Mbagi	Male	Adult	Fore legs Hind legs
6	2547	4053	Ifuguru	Female	Adult	Fore legs & Brisket
7	2548	4067	Serengeti ndogo	Female	Sub-adult	Not infected
8	2553	4062	Hondohondo	Female	Adult	Fore legs
9	2554	4056	Hondohondo	Male	Adult	Fore legs

10	2555	4065/ 4044	Hondohondo	Female	Adult	Not infected
11	2556	4068	Mbagi	Male	Adult	Forelegs
12	2557	4072	Mbagi	Male	Adult	Fore legs
13	2558	4058	Hondohondo	Female	Adult	Fore legs
14	2559	4061	Makutano	Female	Adult	Fore & Hind legs
15	2560	4070/ 4398	Hondohondo	Female	Adult	Fore legs
16	2565	4071	Mbagi	Male	Sub-adult	Fore legs
17	2561	4399	Hondohondo	Male	adult	Fore legs and brisket
18	2564	4400	Serengeti ndogo	Female	Sub adult	Forelegs

Table 1: Giraffe identification (collar/ tag), sex, collaring location/ park area and part of the body affected for giraffes in the treatment trial

RESULTS

Results of the efficacy of various drugs for the treatment trial are shown in Table 2. Out of the 18 collared/ tagged giraffes, only seven giraffes were sighted during every monitoring visit for assessment (fully assessed) and that the remaining 11 giraffes were not seen during every visit for assessment (not fully assessed). For the seven giraffes that were fully assed, only two out of five giraffes treated with antibiotic were fully assessed, only two out of three giraffes treated with ivermectin were full assessed, three out of six giraffes treated with ivermectin-antibiotic combination were full assessed, and (two) negative control giraffes were fully assessed. All two positive control giraffes were among the giraffes that were not seen every monitoring visit for assessment. Most giraffes that were not found in most of the monitoring visits due to failure of the GPS collars to transmit locations/ positions of collared giraffes or sometimes due to failure to immobilize collared giraffes when sighted as a result of high flight distance. Ten (10) GPS collars stopped transmitting location or positions of collared/ tagged giraffes just three months after giraffe collaring/ tagging. Apart from one of the collared giraffes that died on natural cause (predation), the rest of fully assessed giraffes with GSD were seen alive and none had any significant clinical abnormality apart from GSD lesions.

Analysis of efficacy the results for two giraffes treated with antibiotic and fully assessed showed that one of the two giraffes (50%) had significant improvement (50%) and that the second one (50%) had moderate improvement. Gross lesions of significant improvement were changes from encrusted skin to healing skin or smooth and dry skin. Moderate improvement involved changes from scabs to hair regrowth on alopecic patches. Severity of lesions in both giraffes changed from moderate to low severity.

Analysis of efficacy the results for two giraffes treated with ivermectin and fully assessed showed that one giraffe (50%) had high significant improvement with no lesions (50%) and that the other one had moderate improvement at the end of the drug trial. Gross lesions of improvement were skin changes from encrusted and wrinkled skin to smooth skin.

Analysis of efficacy the results for three giraffes treated with a combination of antibiotic and ivermectin and fully assessed showed that two giraffes had significant improvement (66.67%) and one (33.33%) had moderate improvement. Gross lesions of the two giraffes with significant improvement included changes from encrusted skin to scabs and papules and hair regrowth, and that severity of lesions changed from high to low severity.

Generally, gross assessment of lesions in treated giraffes showed that the effectiveness of the drugs was high when given at an early stage of infection (fresh cases) than in advanced or chronic cases of infection. All two negative control giraffes (uninfected control) were sighted and assessed every monitoring trip, and showed that one giraffe (50%) with collar number 4044 and ear tag 2555 was infected with GSD three months after commencement of the study. Lesions were initially small nodules and later progressed to small alopecic lesions.

Unfortunately, all two giraffes that were infected and not treated (negative control) were not sighted for assessment on several occasions of the monitoring visits, and no assessment was on the progression of lesions in infected untreated giraffes. Gross assessment of lesions also showed that treated giraffes that had fresh and chronic multiple lesions were found to have healing scars observed during monitoring, and that some lame giraffes had normal gait one month after treatment. Blood samples, serum, skin biopsy and skin scrapings were collected for laboratory analysis and assessment of lesions as well as for identification of the etiological agent.

SN	Ear tag No.	GPS collar ID	Last collar transmission date	Disease	Treatment given	Gross 08.10.22	Gross 17.2.23	Severity 08.102022	Severity 17.2.23	Efficacy & Comment
1	2545	4063	19.02.2023	Infected	Ivermectin	Encrusted skin, chronic	Not assessed	High	Not assessed	Died on 18.2.23 after immobilization
2	2542	4059	06.02.2023	Infected	Combination	Encrusted skin, chronic		High	Not assessed	Not fully assessed
3	2543	6055	Active	Infected	L.A. Antibiotic	Scabs, fresh	Hair regrowth with nodules	Low	Low	Significant improvement
4	2546	4057	19.02.2023	Infected	Ivermectin	Scabs, fresh	No lesion	Low	No lesion	High significant improvement
5	2544	4054	11.01.2023	Infected	Combination	Encrusted skin, chronic	Scabs	High	Low	Significant improvement
6	2547	4053	11.01.2023	Infected	Ivermectin	Wrinkled skin, chronic	Scabs	Medium	Low	Moderate improvement
7	2548	4067	30.01.2023	Not infected	Control		Not infected	Not infected	No lesion	Not infected
8	2553	4062	Active	Infected	L.A. Antibiotic	Encrusted skin, chronic	Healing skin/ smooth	High	Medium	Moderate improvement
9	2554	4056	Active	Infected	Combination	Encrusted skin, chronic	Healing skin/ smooth	High	Low	Significant improvement
10	2555	4065/ 4044	Active	Not infected	Control	Not infected	Fresh infection	Not infected	Low	Infected after 3 months

11	2556	4068	Active	Infected	Ivermectin	Wrinkled skin, chronic	Not assessed	Medium	Not assessed	Not fully assessed
12	2557	4072	16.12.2023	Infected	Combination	Wrinkled skin, chronic	Not assessed	High	Not assessed	Not fully assessed
13	2558	4058	Active	Infected	Control	Wrinkled skin, fresh	Not assessed	Low	Not assessed	Not fully assessed
14	2559	4061	12.12.2023	Infected	Combination	Encrusted skin, chronic	Not assessed	High	Not assessed	Not fully assessed
15	2560	4070/ 4398		Infected	Control	Scabs, chronic	Scabs	High	Medium	Not fully assessed
16	2565	4071	21.01.2023	Infected	Ivermectin	Scabs	Not assessed		Not assessed	Not fully assessed
17	2561	4399	Active	Infected	L.A. Antibiotic	Encrusted skin, chronic	Not assessed	Not assessed	Not assessed	Not fully assessed
18	2564	4400	29.01.2023	Infected	Combination	Scabs	Scabs	Not assessed	Low	Moderate

Table 2: Collar information and effectiveness of various drugs for treatment of giraffe skin disease in Ruaha National Park

DISCUSSION

The field-based treatment trial showed that the antibiotic& ivermectin drug combination was the most effective in the treatment of GSD in infected giraffes. The results have suggested that the probable causative agent for GSD might be a nematode or a bacteria. The results are in line with results of a survey of an emerging giraffe skin disease of Nubian giraffe (*Giraffa camelopardalis camelopardalis*) of Uganda, which indicated that the causative agent was a unique filarid nematode morphologically similar to *Stephanofilaria spp* (Han et al., 2022). Previous studies of the aetiological agent in histological sections showed the presence of nematodesn and that it is complicated by secondary fungal infection (Epaphras et al., 202014), which recommended the use of anthelmintic and antifungal agents to assess treatment options for GSD. This study did not include testing the efficacy of antifungal in the treatment of GSD due to large volume of injectable antifungal required for large herbivores, unless a concentrated injectable preparation is formulated. The high efficacy of ivermectin & antibiotic combination has provided more evidence that GSD might be further complicated by secondary bacterial infection. Previous studies of GSD in Ruaha National Park isolated 11 different types of fungi isolated on pure cultures and two types of bacteria namely *Staphylococcus saprophyticus* and *Staphylococcus epidermidis* (Mpanduji, et al., 2011).

This treatment trial was affected by failure to find/ trace some of the collared/ tagged and treated animals for full assessment due to failure of collars to transmit locations. It was later realized that the collars failed due to some technical problems as they were a first generation of giraffe collars to be placed on giraffe tails. Based on data collected, it is concluded that GSD responds well to treatment with ivermectin-antibiotic combination or ivermectin alone and that treatment response is high for fresh cases, and might be even high for repeated treatments. To overcome challenges of locating treated giraffes for assessment, and to avoid costs of repeated immobilizations, and in order to assess the efficacy of repeated drug treatments, an indoor controlled treatment trial using giraffes kept in a capture facility (giraffe boma or boma) is recommended in order to reach a conclusion on the causative agent and the drug of choice for GSD.

This study has shown that GSD did not cause any mortality in infected Maasai giraffes as all collared giraffes were seen until the end of the trial, with no clinical abnormalities apart from GSD lesions, indicating that the disease does not impact giraffe survival or population in a short term. The results are similar to GSD lesions in Nubian giraffes that indicated that GSD was relatively well tolerated by giraffe population, and that the overall health impact appeared to be limited (Han et al., 2022).

Based on data collected, it was concluded that GSD responds well to treatment with ivermectin and antibiotic combination or ivermectin alone, and that the efficacy of drugs was high for fresh cases than in chronic cases. To overcome challenges of finding treated giraffes for assessment and costs of repeated giraffe immobilizations, a controlled treatment trial using giraffes kept in an animal capture facility (boma or kraal) is recommended, repeated drug treatments is also recommended to improve drug efficacy. Due to chronic nature of most cases, for current field treatments, it is recommended that treatments with drugs should be repeated on intervals of 7-21 days and that at least three treatments should be done to each animal, 20% long-acting (L.A.) antibiotic should be replaced with 30% L. A. antibiotic 30% that stays longer in the animal body and that topical fungal treatments (pour-on) should be included to control fungal infections. In spite of the fact the current study has shown that GSD is relatively well tolerated in a short term; long term monitoring of collared giraffes should continue using fitted ear tags in order to determine the long-term impact of GSD in giraffe population.

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IMPLEMENTING A CHEMOPROPHYLACTIC PROGRAMME AS A CONSERVATION INCENTIVE FOR THE MAASAI AND SONJO TRIBES IN THE EASTERN SERENGETI

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ABSTRACT

Communities residing in proximity to protected areas tend to exhibit a greater inclination to coexist with carnivores when provided with tangible benefits. Our objective was to investigate community attitudes towards coexisting with carnivores such as lions (*Panthera leo*), leopards (*Panthera pardus*), cheetahs (*Acinonyx jubatus*), spotted hyenas (*Crocuta crocuta*), African wild dogs (*Lycaon pictus*), and black-backed jackals (*Canis mesomelas schmidti*). Employing a pre-test and post-test methodology, we implemented a chemoprophylactic programme as a conservation incentive among the Maasai and Sonjo tribes living adjacent to the eastern part of the Serengeti National Park, Tanzania. Chemoprophylaxis involves preventing infectious diseases using chemical agents. The pre-test outcomes revealed a low willingness from both tribes to coexist with these significant carnivores, with the Sonjo tribe exhibiting less willingness than the Maasai tribe. Post-test results indicated an upswing in their willingness to coexist with large carnivores. This shift was attributed to fewer livestock loss caused by large carnivores compared to losses due to diseases in both tribes. Consequently, this study advocates for increased conservation incentives for local communities to foster a greater willingness to coexist with large carnivores in their habitats.

Key words: *coexistence; willingness; chemoprophylactic programme; large carnivores; livestoc*

INTRODUCTION

Human-carnivore coexistence necessitates the judicious use of both biological and social strategies to mitigate conflicts, thereby diminishing carnivore mortality. Carter and Linnell (2016) argue that effective coexistence involves dynamic yet sustainable states where humans and large carnivores adapt to shared landscapes, governed by institutions ensuring long-term carnivore population persistence, social legitimacy, and tolerable risk levels. This approach is crucial for reducing human-carnivore conflicts and safeguarding carnivores in the future (Woodroffe et al. 2005, Dickman 2010).

Past research indicates that managing conservation conflicts reduces negative impacts on biodiversity (Woodroffe et al. 2005, Lagendijk and Gusset 2008, Vedeld et al. 2012, Redpath et al. 2013). Conflict resolution enhances positive attitudes, supporting conservation initiatives (Conover 2002). Negative interactions, including human attacks and livestock depredation by carnivores, often lead to retaliatory actions, such as poisoning or snaring (Linnell et al. 2001, Hazzah 2006, Romañach et al. 2007, Dar et al. 2009, Abade et al. 2014).

Despite habitat reduction from biodiversity-based human population growth coupled with its extensive and unplanned land uses, efforts should integrate human activities with carnivore conservation (Treves and Karanth 2003). Efficient management practices can enhance coexistence (Linnell et al. 2001). Livestock depredation is a primary cause of human-carnivore conflict in rural areas. Therefore, by implementing consolation programmes, such as a chemoprophylactic initiative, can provide tangible benefits to victims (Breitenmoser 1998; Skonhoft 1998). Chemoprophylaxis, preventing infectious diseases in livestock using chemical agents, has shown promise in improving coexistence (CDPNews 2003). Prevalent diseases in the region included coenurosis, East Coast fever (ECF), Contagious Bovine Pleuropneumonia (CBPP), and anthrax. However, the focus of the chemoprophylactic programme was on addressing helminths infestation and tick-borne haemoparasites, particularly ECF. The ECF, caused by *Theileria parva* transmitted through infected ticks (*Rhipicephalus appendiculatus*), initially affects lymph nodes, then spreads to red blood cells, leading to severe lung edema and eventual death (Kivaria 2007, Gilioli et al. 2009). Coenurosis, a neurological ailment in goats and sheep, is caused by tapeworms of the genus *Taenia multiceps*. Transmission occurs when infected domestic animals and large carnivores contaminate pastures with feces, and ingestible *Coenurus cerebralis* cysts are then swallowed by sheep and goats (Scala and Varcasia 2006, Sharma and Chauhan 2006). CBPP is transmitted through aerosol inhalation of *Mycoplasma mycoides mycoides* (Scott 2014, Almaw et al. 2016). Anthrax, a zoonotic disease, is caused by the *Bacillus anthracis bacterium*. Transmission to humans can occur through consuming infected carcasses or handling infected animal products. The bacterium, lacking an animal reservoir, exists in spore form in the environment and in vegetative form in infected animals. The disease affects all warm-blooded animals, both wild and domestic (Smith et al. 1999, Hugh-Jones 2014).

Therefore, by satisfying local communities with conservation incentives, in our case, implementing chemoprophylactic programme, may reduce conflicts with carnivores. Besides, understanding local attitudes towards carnivores is crucial in conservation planning. Positive attitudes lead to greater willingness to coexist, contributing to carnivore conservation (Hazzah 2006). For example, negative attitudes in African lion habitats contribute to declining populations (Dickman 2017). Promoting local communities' willingness to coexist enhances conservation initiatives (Dickman et al. 2014). Therefore, this study aimed to assess changes in people's willingness to coexist with large carnivores after implementing a chemoprophylactic programme. Two hypotheses were tested: (1) Livestock diseases are the primary cause of losses among the Maasai and Sonjo tribes, surpassing carnivore depredation deaths, and (2) implementing a chemoprophylactic programme would be crucial in reducing livestock losses, consequently improving tolerance towards large carnivores.

METHODS

Study area

Our research was conducted within the Eastern Serengeti ecosystem, specifically in the Loliondo Game Controlled Area (LGCA). The surveyed villages were situated in the LGCA, which is administratively under the Ngorongoro District Council (MNRT 2013). By then (2017), the LGCA encompassed an area of approximately 4500 km^2 (Lyamuya et al. 2016), before gazettement of the Pololeti Game Reserve. Additionally, the Sonjo tribe resides on the eastern border of the LGCA. Geographically, the LGCA was bounded by the Serengeti National Park to the west, the Ngorongoro Conservation Area to the south, Kenya to the north, and Lake Natron to the east (Masenga and Mentzel 2005, Lyamuya et al. 2016).

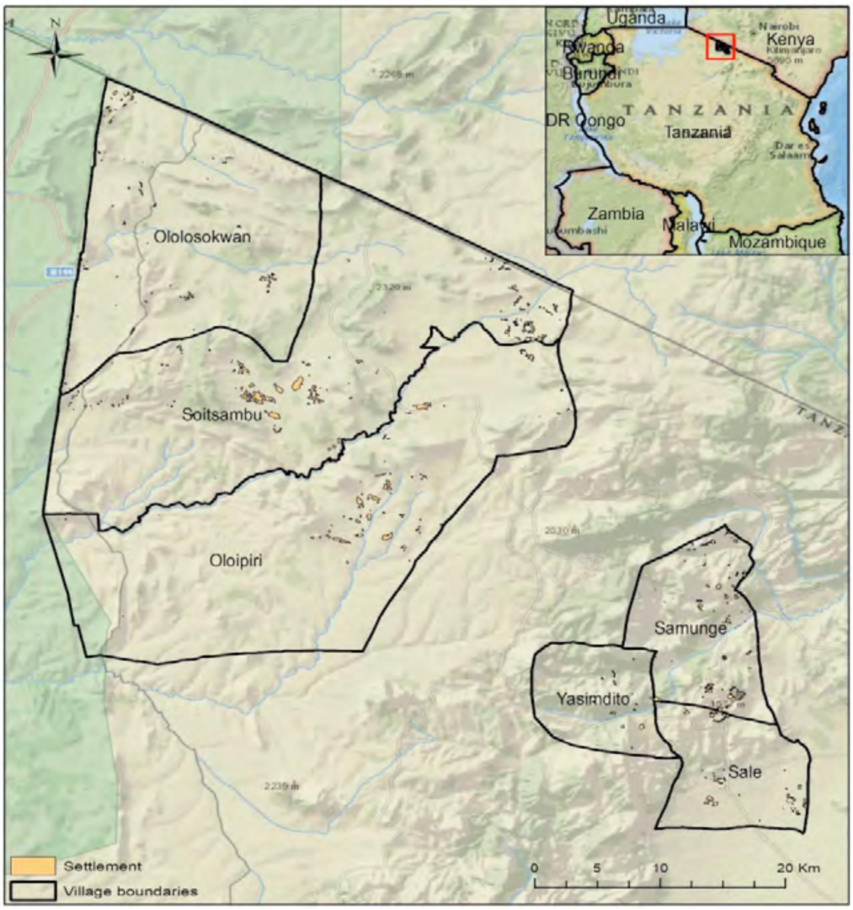

Figure 1: Location of the study villages of Ololosokwan, Soitsambu, Oloipiri, Samunge, Sale, and Yasimdito in the Eastern Serengeti ecosystem before new recategorization of Pololeti Game Reserve.

Data collection

Data was collected in September 2016 and February 2017 through a pre-test and post-test questionnaire survey. In September 2016, the pre-test aimed to gather responses from the Maasai and Sonjo tribes regarding their willingness to coexist with large carnivores before the introduction of the conservation incentive (chemoprophylactic programme). The assessment of people's willingness to coexist was conducted openly, categorizing responses as positive, neutral, or negative. The specific question asked was, "Will conservation incentives be helpful to motivate your willingness to coexist with large carnivores?" Respondents indicated their willingness based on whether they agreed that conservation incentives promote a positive attitude towards overlooking livestock loss due to large carnivore depredation (positive), disagreed (negative), or had no opinion (neutral). To maintain unbiased responses, information about the upcoming incentive was not disclosed. Concurrently, we also documented the reported number of livestock losses caused by large carnivores and diseases in the last two years (2015 and 2016).

Following a four-month period (February 2017), a post-test survey was conducted concurrently with the administration of chemoprophylaxis to the livestock of our previous respondents. The chemoprophylactic programme was implemented by a veterinary officer from the Tanzania Wildlife Research Institute (TAWIRI). Two sets of drugs were administered: (1) oxytetracycline hydrochloride 20%, a long-acting antibiotic effective against a broad spectrum of gram-positive and gram-negative bacteria, as well as other microorganisms like *Mycoplasma pneumoniae*, *Coxiella burnetii*, and *Plasmodium spp*.; and (2) albendazole 10%, a broad-spectrum anthelminthic for the prophylaxis and treatment of immature and mature infectious gastrointestinal nematodes, lung worms, tape worms, and trematodes.

In February, some respondents relocated their livestock to other villages due to drought, causing a reduction in our sample size from 180 to 120 respondents. The same question regarding their willingness to coexist with large carnivores, given the receipt of conservation incentives, was posed as in the previous survey. In the Maasai and Sonjo tribes, decision-making is predominantly in the hands of men, resulting in a higher participation of male respondents compared to females (Table 1). Achieving gender balance poses a challenge, requiring additional time in the field (Mbise et al. 2018). Respondents were categorized into three age groups: youth (18–35 years), adult (36–49 years), and elderly (50 years and above).

Data analyses

Data analyses were conducted using SPSS version 27 (IBM 2022), employing various statistical methods, including multinomial logistic regression, paired samples t-tests, one-way ANOVA tests, and chi-square tests. Multinomial logistic regression aimed to identify the predictor variable explaining the most variation in people's willingness to coexist with large carnivores. Paired t-tests were employed to assess potential changes in willingness to coexist within both the Maasai and Sonjo tribes. To elucidate differences in livestock losses attributable to diseases and depredation, a one-way ANOVA test was utilized. The chi-square test was applied to explain variations in disease frequency between the two tribes. Data normality was assessed, with a significance level set below 0.05 probability level.

RESULTS

Demographic characteristic of the respondents

The majority of respondents fell into the adult group (Table 1). Primary education was the most common level of education among respondents (Table 1), and all participants belonged to either the Maasai or Sonjo tribes (Table 1).

Table 1: Demographic variables of the respondents

		N	%
Sex	Male	97	80.8
	Female	23	19.2
Age	Youth	39	32.5
	Adult	49	40.8
	Elderly	32	26.7
Education	Informal	35	29.2
	Primary	71	59.2
	Secondary	14	11.6
Tribe	Maasai	60	50.0
	Sonjo	60	50.0

People's willingness to coexist with large carnivores before introducing the conservation incentive

Examining people's willingness to coexist with large carnivores before introducing the conservation incentive, a multinomial logistic regression analysis was conducted. The analysis tested the variation in willingness (categorized as positive, neutral, and negative) using three independent variables: tribe, age, and education. The test yielded statistical significance (Pearson $\chi2 = 23.896$, df = 10, p = 0.008, Nagelkerke $r^2 = 0.237$). However, tribe emerged as the sole predictor variable explaining the variation in people's willingness to coexist with large carnivores. Both tribes exhibited a lower willingness to coexist, with the Sonjo tribe displaying less willingness compared to the Maasai tribe (Pearson $\chi2 = 8.159$, df = 2, p = 0.017; see Table 2).

Table 2: People's willingness to coexist with large carnivores before introducing the conservation incentive

Tribe	Positive		Neutral		Negative	
	N	%	N	%	N	%
Maasai	7	10	17	30	36	60
Sonjo	1	1.7	6	10	53	88.3

People's willingness to coexist with large carnivores after implementing the conservation incentive

To elucidate the variation in people's willingness to coexist with large carnivores following the implementation of the chemoprophylactic programme (categorized as positive, neutral, and negative), a multinomial logistic regression was employed, considering three independent variables: tribe, age, and education. The test yielded statistical significance (Pearson $\chi2 = 47.917$, df = 10, $p < 0.0001$, df = 10, Nagelkerke $r^2 = 0.427$). Once again, tribe emerged as the sole predictor variable explaining this variation, with the Maasai tribe displaying a higher willingness compared to the Sonjo tribe (Pearson $\chi2 = 36.149$, df = 2, $p < 0.0001$; refer to Table 3). Post-implementation of the conservation incentive, the willingness to coexist with large carnivores increased in both tribes (Maasai: Paired samples t-test, $t = 7.812$, $df = 59$, $p < 0.0001$; Sonjo: Paired samples t-test, $t = 15.108$, $df = 59$, $p < 0.0001$) (Tables 2 & 3).

Table 3: People's willingness to coexist with large carnivores after implementing the conservation incentive

Tribe	Positive		Neutral		Negative	
	N	%	N	%	N	%
Maasai	55	91.7	5	8.3	0	0
Sonjo	33	55	4	6.7	23	38.3

Factors contributing to livestock losses

The results indicated a significantly lower number of livestock losses due to large carnivore depredation compared to losses caused by diseases in both tribes (Maasai: $t = -5.373$, $df = 3$ and 59, $p < 0.0001$; Sonjo: $t = -7.820$, $df = 3$ and 59, $p < 0.0001$) (see Table 4). Notably, goats and sheep exhibited a higher susceptibility to diseases than cattle in both tribes ($F = 34.89$, $df = 1$ and 118, $p < 0.0001$) and ($F = 25.79$, $df = 1$ and 118, $p < 0.0001$), respectively. Furthermore, predators were responsible for a significantly greater number of losses among goats and sheep compared to cattle ($F = 9.47$, $df = 1$ and 118, $p = 0.003$), ($F = 9.16$, $df = 1$ and 118, $p = 0.009$), and ($F = 20.59$, $df = 1$ and 118, $p < 0.0001$), respectively (refer to Table 4).

Table 4: A detailed comparison of livestock losses related to diseases and carnivore depredation in the Maasai and Sonjo tribes.

Tribe		Cattle loss-diseases	Goat loss-diseases	Sheep loss-diseases	Depredated cattle	Depredated goats	Depredated sheep
Maasai	Mean	12.7	25.8	20.7	2.5	3.2	14.7
	Std.	15.4	21.1	16.5	1.9	2.5	13
Sonjo	Mean	5.9	10.4	6.7	1.6	1.5	1.6
	Std.	5.7	8.8	6.6	1	0.8	2.7

In both the Maasai and Sonjo tribes, East Coast Fever and Contagious Bovine Pleuropneumonia were identified as the primary diseases leading to cattle losses, respectively. However, the disparity between the two tribes did not achieve statistical significance (Pearson $\chi 2 = 1.427$, $df = 2$, $p = 0.49$; consult Table 5). For goats and sheep, coenurosis proved to be a more prevalent issue than anthrax and East Coast Fever, with no discernible differences between the two tribes (Pearson $\chi 2 = 0.962$, $df = 2$, $p = 0.81$; refer to Table 5).

Table 5: Losses due to different diseases for cattle, goat, and sheep

	Diseases-cattle			Diseases-goat		Diseases-sheep		
Tribe	Anthrax	CBPP	ECF	Coenurosis	Anthrax	Coenurosis	Anthrax	ECF
Maasai	5	18	25	46	13	29	13	15
%	10.4	37.5	52.1	78	22	50.9	22.8	26.3
Sonjo	4	8	8	37	14	20	13	10
%	20	40	40	72.5	27.5	46.5	30.2	23.3

DISCUSSION

The findings of this study shed light on potential strategies for communities coexisting with large carnivores, particularly in the context of the eastern Serengeti ecosystem. The provision of cost-effective and tangible benefits to local people, who bear the brunt of conservation costs, emerges as a viable approach. This is particularly pertinent in developing countries, notably in African countries, where many governments have limited resources to fully compensate individuals for livestock losses to predators. In the Maasai and Sonjo tribes of the eastern Serengeti ecosystem, diseases posed a more significant threat to livestock than carnivore depredation. Exploring alternatives to foster willingness to tolerate depredation, such as treating livestock against diseases, offers a pathway towards harmonious coexistence between communities and predators, especially within these tribes. However, it is crucial to approach this alternative cautiously. In the long term, increasing livestock numbers may diminish wild prey, elevating the risk of depredation, conflicts, and retaliatory actions. Balancing these factors is essential for the sustainable coexistence of people and predators in the studied tribes.

The findings of this study highlighted a contrast in the willingness to coexist with large carnivores between the Maasai and Sonjo tribes, particularly concerning the treatment of livestock against diseases, a more significant cause of livestock loss than large carnivore depredation. The Maasai tribe exhibited a greater willingness to coexist under the condition of treating livestock, whereas the Sonjo tribe members maintained a more rigid stance, even after receiving a conservation incentive. Previous research by Bencin et al. (2016) and Hazzah et al. (2017) underscores the importance of influencing human behavior to appreciate the ecological and economic benefits of large carnivores for their effective conservation. Financial compensation following livestock depredation, as highlighted by CDPNews (2003) and Naughton-Treves et al. (2003), is currently deemed less effective and unsustainable.

In exploring alternatives, this study assessed people's willingness to coexist with large carnivores before and after the implementation of a chemoprophylactic program, serving as an alternative conservation incentive. The positive reception of the program was influenced by the fact that both the Maasai and Sonjo communities experienced higher livestock losses due to diseases than depredation. Respondents expressed a willingness to accept losses to depredation, given the low rates, while disease-related losses were three times higher for the Maasai tribe and five times for the Sonjo tribe. Establishing a sustainable program to treat livestock against diseases emerges as a potential avenue to enhance willingness for coexistence with large carnivores.

Communities residing near or within protected areas often exhibit reduced willingness to coexist with large carnivores (Spira 2014). Addressing a prolonged history of conflict poses a challenge for policymakers and researchers (Kideghesho et al. 2007). Sustainable coexistence becomes more probable if communities perceive tangible benefits, whether direct or indirect, arising from the presence of carnivores (Newmark et al. 1993, Bencin et al. 2016). Conservation incentives provided to such communities contribute to positive behavior and perceptions towards carnivores in their vicinity (Smith 2005, Lagendijk and Gusset 2008).

As these communities bear the costs of carnivore conservation, a sense of ownership develops over time when tangible benefits are realized, ultimately reducing human-carnivore conflict (Newmark et al. 1993, Kidegesho 2008). Tangible benefits also enhance tolerance for the costs associated with large carnivores (Lagendijk and Gusset 2008). Minimizing existing human-carnivore conflicts, particularly livestock depredation, is imperative for the coexistence of people and carnivores (Newmark et al. 1993, Nyahongo and Røskaft 2012, Lyamuya et al. 2014, Mbise et al. 2018).

In many savannah ecosystems, pastoralists coexist with large carnivores, with diseases posing the primary threat to livestock, followed by depredation (Nyahongo and Røskaft 2012). The likelihood of livestock depredation is higher when large carnivores and livestock share the same landscape (Spira 2014, Mbise et al. 2018). Losses from diseases and depredation adversely affect the livelihoods of affected communities (Gifford-Gonzalez 2000, Nyahongo and Røskaft 2012). Controlling diseases with multi-host pathogens is challenging (Lembo et al. 2008), but with proper awareness and sensitization campaigns, communities can mitigate disease severity in their areas.

In tropical regions, the prevalence of diseases impacting livestock is a major cause of income loss, particularly for pastoral communities heavily reliant on livestock for survival (Gifford-Gonzalez 2000). Various measures, including chemoprophylaxis, can be employed to treat livestock and boost immunity against diseases (Jibbo et al. 2010). However, in developing countries, lack of disease awareness often leads to untreated livestock, with many communities maintaining large herds with suboptimal health due to limited education and awareness. Large livestock herds hold significant value in both the Maasai and Sonjo communities, symbolizing wealth and prestige (Hodgson 2011). Consequently, there is a critical need to raise awareness about the benefits of selling a few animals to acquire drugs for treating the rest, especially considering the limited formal education levels among pastoralists influencing important life decisions.

Awareness on diseases proves crucial for these communities, as some livestock-affecting diseases are preventable and controllable with adequate education and awareness. For example, during our chemoprophylactic program, a significant number of sheep and goats succumbed to coenurosis disease. Implementing veterinary guidelines, including deworming domestic dogs and providing chemoprophylaxis for livestock, could substantially mitigate the longstanding issue of livestock loss due to diseases. Our chemoprophylactic programme received commendation for contributing to the overall health improvement of livestock that underwent treatment. Given the poor condition of most livestock due to drought, they were particularly susceptible to diseases. Our findings supported both hypotheses: diseases contribute more to livestock losses than carnivore depredation, and treating livestock against diseases enhances tolerance for depredation losses. Consequently, people's willingness to coexist with large carnivores increased following the implementation of the chemoprophylactic program.

In conclusion, achieving harmonious coexistence between humans and large carnivores is closely linked to providing tangible benefits to communities sharing their habitat with these species. Treating the livestock of the Maasai and Sonjo tribes against diseases yields tangible benefits that justify the costs associated with cohabiting with large carnivores. However, precautions are necessary, as treating livestock against diseases may increase the livestock population, contributing to habitat destruction and potential to human-carnivore conflicts upsurge.

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FLORA RESOURCES OF THE MIKUMI NATIONAL PARK: AN INSIGHT FOR STRATEGIC MANAGEMENT AND CONSERVATION OF PROTECTED AREAS IN TANZANIA

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ABSTRACT

The flora in protected areas represents important assets for the wildlife such as forage, shelter, breeding sites, and water. The floristic composition of Mikumi National Park (MINAPA) is fragmented, and partially understood in research and management circles, limiting the implementation of feasible conservation and management techniques. Plant species records were collected from different historical works using literature search, and herbarium verification. Additional species records were abtained from the most recent in 2021, obtained using systematic random surveys. We analyzed plant species records from unpublished surveys (1960s-1990s), and a most recent survey in 2021 to update the list for MINAPA based on the classification of the APG IV. In total, 951 species records were organized, within 504 genera and 124 families, of which 35 species were listed in the IUCN red list whereby 15 (1.6%) were vulnerable, seven (0.7%) were Near Threatened, 10 (1.0%) were Endangered and three (0.3%) were Critically Endangered (CR). Sixteen (16) species were endemic to Tanzania from the 1960s-1990s or curent surveys or both? Seventy thousand and seventy-eight (778) species were from the 1960s-1990s surveys, distributed across 421 genera and 106 families, 12 of which (1.5%) were in the IUCN red list. One hundred seventy-three (18.2%) were newly recorded in 2021 (not in the 1960s-1990s list). The newly recorded were distributed across 148 genera and 58 families, including 21 (2.2%) species in the IUCN red list, and thirteen (13) species endemic to Tanzania. In general, this work significantly improved our understanding of the flora of MINAPA and draws concern for ensuring regular surveys to update floral resources status in protected areas where reports are of the old taxonomic nomenclature. It contributes to the improvement of scientific research and management techniques under the ongoing changes in climatic conditions.

Keywords: Flora, IUCN Red Listed Plants, plant composition, botanical surveys, plant species records.

INTRODUCTION

Biological assessments like floral composition, species diversity, and vegetation structural analysis provide a clear understanding of ecological characteristics, and ecosystem functions and, thus are necessary for ecosystem management (Ali et al., 2017; Gurr et al., 2017; Kremen, 2005) . Studies on flora composition are necessary for protected areas (PAs) which is also part of the ecosystem management as they provide a clear understanding of ecological characteristics, and potentials in ecosystem functioning (Fielder et al. 2008). The flora in ecosystems represents important assets for the wildlife such as forage, shelter, breeding sites, and water. Vegetation surveys help to identify plant diversity (Koyama et al. 2021), which is the baseline in the management of the biodiversity elements as well as monitoring changes that are happening over time (Castri 1990; Spellerberg 2005). It is key to fulfilling obligations and commitments in wildlife research in Tanzania (Dowie 2011; Plan 2001), and those of the Conservation of Biological Diversity (CBD) at large (Lausche 2011), as it helps meet the requirements of the Convention on Biological Diversity (CBD) (2012) (Day et al. 2012). The CBD calls for the facilitation of all-taxa inventories in areas of high conservation priority, including the specific ecosystems. MINAPA is among the most important PAs in Southern Tanzania and is currently among the four PAs that are priority areas where the Government of Tanzania aims to raise the level of tourism and improve community livelihood (Ndossy 2020; Vedeld et al. 2012). Therefore, a clear understanding of vegetation resources in the MINAPA will help the improvement of resources management techniques, and knowledge on species-specific conservation status and attract investment in scientific research.

This study provides an inclusive and updated floristic status, using the currently accepted names of families, genera, and species for the recorded plants in the MINAPA. The study also analyzes the contribution of the surveys conducted under the support of the Resilient Natural Resource Management for Tourism and Growth Project (REGROW) to the old, existed plant records for MINAPA based on the classification of the Angiosperm Phylogeny Group (AGP IV) for the orders and families of flowering plants. The study deals with the presently accepted family classification and taxa nomenclature and virtually complements previous studies, including the works of Richard Wingfield in 1975 and by John Lovett and Guy Norton (JL-GN) in 1975-1981 and others for plants reported to exist within the MINAPA. It compiled the floristic composition from previous surveys and combined with the most recent (year 2021) surveys, with specific objectives to 1) collect available published and unpublished survey data in MINAPA; 2) determine current vegetation composition of MINAPA and 3) produce the most up-to-date floristic checklist of MINAPA.

Background of the Research

The various morphological features and different climate regimes in the MINAPA create unique habitat types, and species endangered as well as endemic plants. The central and north are savanna dominated with *Acacia* (sensu lato)*, Adansonia digitata* L. (baobab)*, Tamarindus indica (*L*)* and some palm tree species, while the southern part is marked by Miombo vegetation. Furthermore, the Malunde Mountains (07° 24’S, 37°18’ E) is a 450-ha, patch of Afromontane rainforest in the southeast is mountainous and is part of the Eastern Arc Mountain. It is uniquely characterized by the Afromontane rainforest with canopy tree species ranging from 20 to 40 m tall, in which previous works suggested high biodiversity with a variety of threatened species (Lovett and Norton 1989). Habitat types in MINAPA are described to include woodland, open woodland, wooded grassland, floodplain, riverine and Afromontane Forest. The Park supports varieties of fauna and flora, which makes it of great conservation importance.

Vegetation surveys conducted in MINAPA occur in fragments and many are unpublished, ending up with fragmented and unorganized information on species. Because of this, there is an apparent gap in the available information, including a lack of critical literature reviews and concurrent field surveys covering the entire area. The oldest plant species records for Mikumi National Park dates back to the 1960s-1970s, by J. Procter in 1965, 1967, 1970 and1973, S.A. Renvoizem in 1968, P. Ole Sayalel in 1975, Herbert Lyaruu in 1975, Richard Wingfield in 1975 and1976. Herbert Lyaruu and Guy Norton (HLGN) in 1975, and L. B. Mwasumbi in 1976. However, most of the early collections distributed in central, central east and along the Morogoro-Iringa Highway areas of MINAPA, including the Vuma Hills forest, Kikwaraza, Msindazi, Kikobora, Mkuluwili, Chamgore, and Mkata flood plain with an altitude ranging from 300 to 800masl). The specimens were deposited at the herbarium of the University of Dar es Salaam, including several of them were kept at MINAPA. Hard copies of previously recorded species records were obtained at the ecology office of MINAPA. Methods of classification used in such previous lists are not updated and do not use the modern classification of the Angiosperm Phylogeny Group for the orders and families of flowering plants (APG IV, 2016). The Tanzania Wildlife Research Institute (TAWIRI) conducted the latest vegetation assessment in 2021; under the REGROW write it in long form first project. Therefore, to ensure an organized data on flora resources, a critical review is currently of high need, which should include an analysis of the floristic records available for understanding the detailed flora. This review of plant species was the first attempt in MINAPA to collate information from vegetation studies to form one inclusive work and provide an updated checklist, and conduct a quantitative analysis of the flora in MINAPA, a historically and ecologically important wildlife conservation area in southern Tanzania.

MATERIALS AND METHODS

Study Area

Mikumi National Park (MINAPA) is the ninth largest among 21 National Parks in Tanzania located in the central-eastern part of the country, covering 3,230 km². It extends from 37°00’ to 37°30’E and from 7°00’ to 7°45’S (Figure 1) westward towards Nyerere National Park (part of the former Selous Game Reserve). The Park supports a diverse array of fauna and flora, which makes it of great conservation importance. The altitude ranges from 430 to 430m a.s.l in the south and 1270 m a.s.l at the Peak of Malundwe Mountain, the only part of the Eastern Arc Mountains in Tanzania, which is free from uncontrolled human disturbance. The overall mean annual rainfall is 860 mm and the annual average temperature is 25°C. MINAPA has three major catchment river systems namely; the Ruaha, Ruvu, and Wami catchments. The Ruaha catchment flows southward from about the third of the southwestern portion of the park to the Ruaha river system. The Ruvu catchment flows south to the southeast from Malundwe Mountains to the Ruvu river system and the Wami catchment flows north along with the Mkata river system in about a third of north portion of the parking area into the Wami river system.

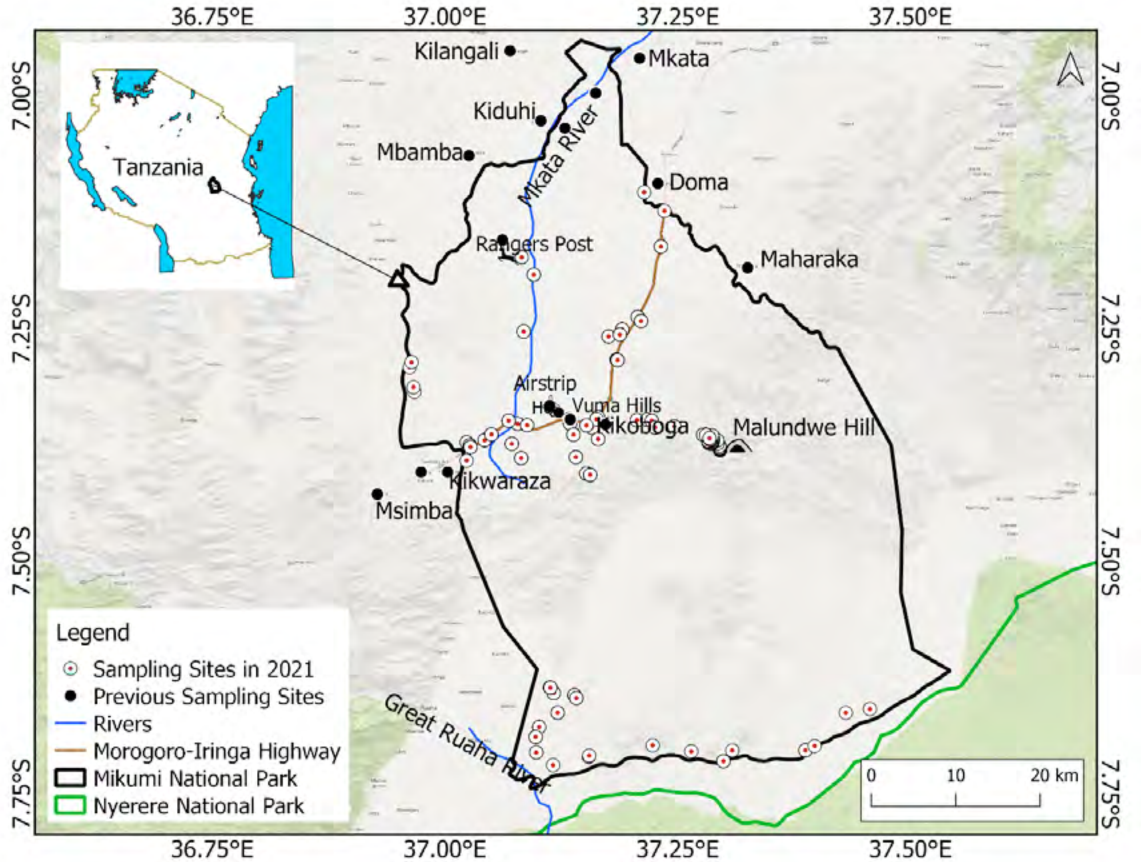

Fig. 1. Map of Mikumi National Park showing the location in Tanzania and sampling areas for previous and recent surveys

Data collection

Plant species data for the checklist of MINAPA were obtained from three primary sources. Firstly, collection records collected during previous surveys, which spread across 1960s-1990s. The data collection involved literature search and herbarium verification. All names of plant species were digitized in Excel spreadsheet and curated by taking species information from the voucher specimens existed, both at the herbarium room in Mikumi National Park and at the University of Dar es Salaam, Tanzania. Secondly, collection records collected during floristic surveys carried out in 2021. Different vegetation patches were visited and surveyed at two seasons (dry and wet) to mainly cover the area where there had been few or no previous collections. The investigations included plot sampling and random walks while recording plant species. Details of collected specimens were recorded in a notebook. Information such as lifeform, habitat, and collector details were recorded where possible in the field as well. The Tanzania Wildlife Research Institute (TAWIRI) documented the 2021 records during the implementation of the Resilient Natural Resources Management for Tourism and Growth (REGROW) project, under the sponsorship and supervision of Ministry of Natural Resources and Tourism in Tanzania (MNRT). Sampling sites were based on vegetation heterogeneity/homogeneity and established nested sampling plots along transects. Sampling plots were 20x20m ($400m^2$) for trees, 5x5m ($25m^2$) for shrubs, and 1x1m ($1m^2$) for herbs and grasses as guided by (Anitha et al. 2009). We identified all plant species and recorded in each plot, including habitat types, by the help of experienced botanists. We recorded unique species found outside the plots. Species not well identified in the field were collected, and later verified using the voucher specimens at the herbarium of the University of Dar es Salaam (UDSM herbarium).

Data Analysis

A detailed review of plant species records was compiled for all surveys (surveys of 1960s-1990s and the recent surveys in 2021). Taxonomic contributions from records were made by compiling the families, genera, and species, and update the nomenclatures according to the Angiosperm Phylogeny Group for the orders and families of flowering plants (APG IV 2016). Family and species circumscription, as well as spelling, authorities, and synonyms of scientific names, were updated based on online databases such as African plant database (www.villege.ch/musinfo/bd/cjb/africa), and Catalogue of life (Hobern et al. 2021). Finally, we identified the conservation status of species based on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2019)

In the updated checklist we have developed, the currently accepted name for the species is first provided and then the synonym (usually the old name). Furthermore, the species list presented have been arranged in major groups, namely Pteridophytes, Dicotyledons, and Monocotyledons. Plant families are arranged alphabetically within each major plant group, followed by genera and species (also alphabetically) within each family.

We compiled the habitats where the species were recorded to know the contribution of prominent habitat types in terms of taxonomic richness. Descriptive statistics, specifically percentage distribution histograms and tableswas used to calculate the proportional taxonomical contribution in terms of per survey period/group, IUCN conservation status was carried out in R software version 4.2.1 (R Core Team 2022). The importance of each family and genus was measured by the proportion of its species and genera to the total number of recorded species, genera, and families in the study area (species/genera, species/families, and genera/families' ratios). We also assessed the proportional contribution of the both the current species records to the MINAPA flora in terms of species that are listed in the IUCN Red Lists as VU, EN, and CR.

Results

The Flora records from historical surveys conducted in MINAPA

The major historical surveys by various scientists are shown in Figure 2. Conducted by J. Procter, in 1965 then by S.A. Renvoize in 1968, who contribute 1.8% and 1.5% respectively in the species checklist, The other oldest known surveys in this study were carried out by P. Ole Sayalel in 1975, 1976, and 1977, had the highest number of records (23.6%), followed by Richard Wingfield in 1975 and John Lovertt and Guy Norton (JL-GN), Herbert Lyaruu (HL), who formed the Animal Behavior Research Unit team (ABRU) in 1977 (Figure 2). In total, the old records make 79.7% contribution while the most recent records in 2021 (Bukombe et al. 2021-unpublished list) under the support of REGROW project, make 20.3% additional records for MINAPA (Figure 2).

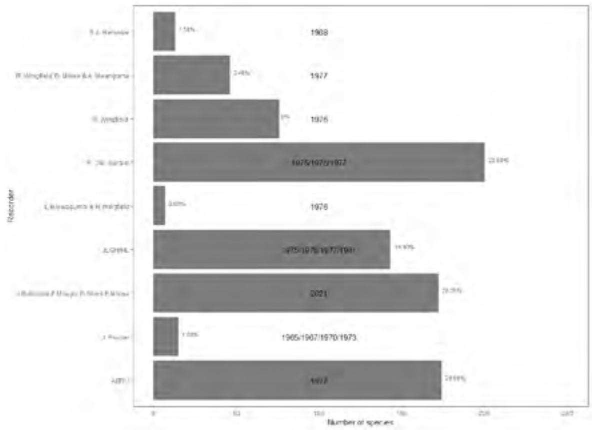

Fig. 2: Plant recorders/project involved in Mikumi National Park since 1960s

The Families of the Floristic Records during the 1960s-1990s Surveys

Table 1A indicated the old species records of which eight major families (each with at least 25 species) had 43% and 50% of the total genera and species respectively. Among these, the most dominant family was Poaceae, having 12% of all genera and 15% of species, followed by the family Fabaceae with 7% of all genera and 8% of all species. These old species records were recorded since 1960s to 1990s, and were ca. 778 species in total, distributed in 421 genera and 106 families. Dicotyledonous plants dominated these.

Table 1. Major plant family records (A) during the 1960s-1990s and (B) in 2021 surveys.

SN	Family	Genus	Number of Species	% of genera	% of species
	A: Eight (8) Major plant family records in the 1960s-1990s				
1	Poaceae	52	114	12	15
2	Fabaceae	29	66	7	8
3	Rubiaceae	22	44	5	6
4	Cyperaceae	8	41	2	5
5	Asteraceae	27	35	6	5

6	Euphorbiaceae	18	33	4	4
7	Acanthaceae	15	28	4	4
8	Caesalpinioideae	13	25	3	3
TOTAL		**184**	**386**	**43**	**50**
	B: Eight (8) Major plant family records in 2021				
1	Rubiaceae	15	22	10.2	12.8
2	Annonaceae	6	10	5.4	5.8
3	Caesalpinioideae	8	10	5.4	5.8
4	Fabaceae	9	10	6.1	5.8
5	Euphorbiaceae	8	8	5.4	4.7
6	Poaceae	6	8	4.1	4.7
7	Asteraceae	6	7	4.1	4.1
8	Sapindaceae	6	6	4.1	3.5
TOTAL		**64**	**81**	**44.8**	**47.2**

The Major Families of the additional plants recently recorded in 2021 surveys

The species that were newly recorded in 2021 were ca. 173 in total and were distributed in 147 genera and 58 families. These species were newly added to the previous list (1960s-1990s records). They were in 48 families of dicotyledonous plants, nine families of monocotyledonous and 1 family of pteridophytes. Therefore, like for the old records, the new records were dominated by dicotyledons. The eight topmost, here referred to as Major Families, were those, which each had at least six species. In total, the major families had 45% genera of all and 47% of all species (Table 1B). These major families recorded in 2021 were dominated by the family Rubiaceae, having 10.2% of all genera and 12.8% of all species, followed by the family Annonaceae with 5.4% of all genera and 5.8% of all species.

Updated floristic checklist of MINAPA

The updated plant list of MINAPA combines both the 1960s-1990s and the most recent in 2021 records (see Table 6) and was developed, based on the current detailed review of the vegetation resources, the checklist has a total of ca. 951 species (Table 2) (the sum of the 1960s-1990s and the most recent records in 2021). The list is taxonomically distributed among 503 genera and 124 families. Overall, the Pteridophytes were represented by three families, four genera, and four species; Monocotyledons by 23 families, 98 genera, and 218 species; and Dicotyledons by 98 families, 401 genera, and 729 species (Table 2). Dicotyledonous plants dominated the species richness in MINAPA.

Table 2. Number of species of the different taxonomic groups recorded in the Mikumi National Park.

Plant groups	Families	Genera	Number of Species
Dicotyledons	98	401	729
Monocotyledons	23	98	218
Pteridophytes	3	4	4
Total	**124**	**503**	**951**

The updated species checklist of MINAPA has 11 prominent families. These were families having atleast 20 species records each. The family *Poaceae* was the most prominent comprising 11% (n=54) of all genera and 13%, (n=128) of all species, followed by Fabaceae with 8% of all genera, and Rubiaceae with 7% of all genera (Table 3). Table 4 shows the prominent general recorded based on the number of species. The genus Cyperus in the Poaceae family is the largest comprising 5% of the total species in the MINAPA. Furthermore, thirty (30) families had 1% (having 5 to 13 species), and 80 families possessed only a single species each (Table 6).

Table 3. The eleven prominent families in the updated checklist of MINAPA

SN	Family	Number of Genera	Number of Species	% of genera from the Total of Updated List	% of species from the Total of Updated List	% of genera from the Total of Major Families	% of species from the Total of Major Families
1	Poaceae	54	122	11	13	29	65
2	Fabaceae	33	76	7	8	18	41
3	Rubiaceae	32	66	6	7	17	35
4	Cyperaceae	8	43	2	5	4	23
5	Asteraceae	30	42	6	4	16	22
6	Euphorbiaceae	23	41	5	4	12	22
7	Caesalpinioideae	19	35	4	4	10	19
8	Acanthaceae	19	32	4	3	10	17
9	Convolvulaceae	5	23	1	2	3	12
10	Mimosoideae	8	23	2	2	4	12
11	Labiatae	10	21	2	2	5	11
Total of Major Families		**187**	**402**	**50**	**54**		
Total of Updated List		**503**	**951**				

Major Life-forms

Based on the known plant morphology (life form) spectra, the updated checklist of plant species in the MINAPA can form seven groups. The most frequent life forms were herbs, with 407 (43%) out of the total number of species, followed by trees, with 295 (31%) species, grasses, with 122 (13%) species, shrubs, 8% species, sedges, 4.5% species, lianas, 3 (0.03%) species, and hemi-climbers, 2 (0.02%) species. In terms of the record status, the life forms of both the new and old records are proportionally more or less similar. However, records collected in 2021 are mostly trees followed by herbs whereas the old record include mostly herbs followed by trees (Figure 3).

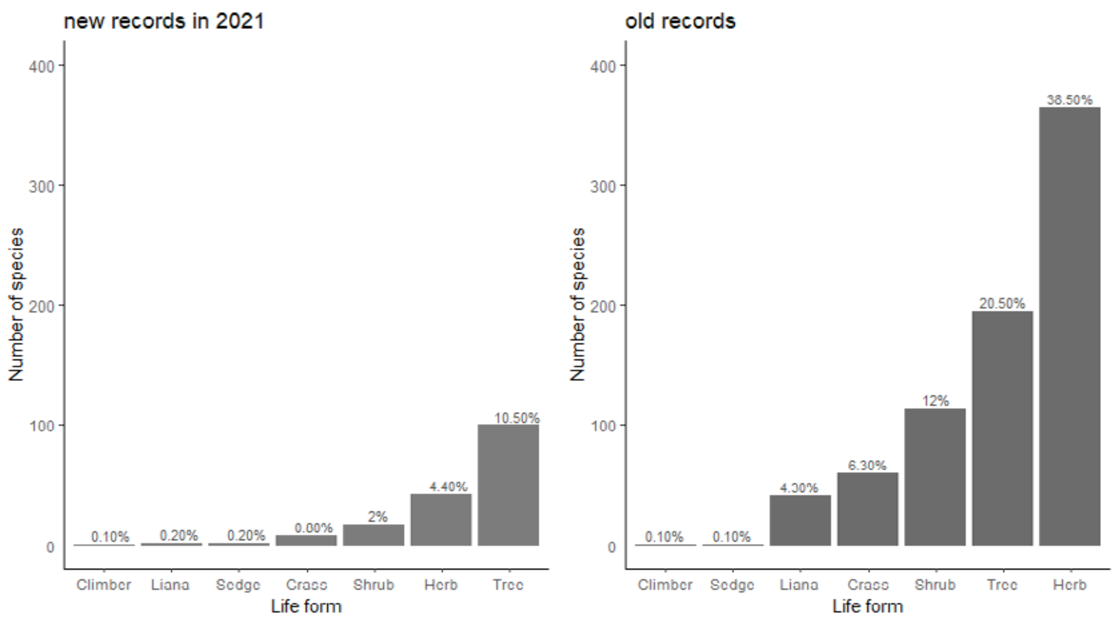

Fig. 3. The plant life forms recorded in MINAPA.

Plant species of Conservation concern

Thirty-five 35 (3.7%) of ca. 951 species records in the updated checklist are listed in the IUCN Red List (Table 4). Of all 35 red listed species records, 15 (1.6%) were vulnerable, 7 (0.7%) were Near threatened, 10 (1.0%) were Endangered (EN) and 3 (0.3%) were Critically endangered (CR), as shown in Tables 1A &B of attached lists, and were dominated by trees, followed by herbs (Table 4). Twenty-one (2.2%) species of the total 35 Red listed species records were newly recorded (additional records) in 2021. Moreover, 16 species out of the 35 IUCN listed species are endemic to Tanzania, of which only three were from the 1960s-1990s surveys whereas 13 of them were from the survey conducted in 2021 (Table 5).

Table 4. Species of conservation value in the UNCN Red List recorded in the Mikumi National Park.

Conservation Status	Total	Year Recorded	Herb	Shrub	Tree	Total
CR	3	2021			2	**2**
		1960s-1990s	1			**1**
EN	10	2021	1	2	5	**8**
		1960s-1990s	2			**2**
NT	7	2021		1	3	**4**
		1960s-1990s	1		2	**3**
VU	15	2021		1	6	**7**
		1960s-1990s	2	1	5	**8**
Total	**35**		**7**	**5**	**23**	**35**

Table 5. Plant species endemic to Tanzania recorded from 1960s to 2021 in Mikumi National Park

SN	Species name	Life-Form	IUCN Status	Author	Year
1	*Zenkerella perplexa*	Tree	CR	Temu	2021
2	*Euphorbia prostrata*	Herb	CR	Ait	
3	*Coffea kihansiensis*	Tree	CR	A.P. Davis & Mvungi	2021
4	*Uvariodendron oligocarpum*	Tree	EN	Verdc.	2021
5	*Uvariodendron pycnophyllum*	Tree	EN	(Diels) R. E. Fr.	2021
6	*Uvariodendron usambarense*	Tree	EN	R. E. Fr.	2021
7	*Cola discoglypremnophylla*	Herb	EN	Brenan & A. P. D. Jones	2021
8	*Xylia Africana*	Tree	EN	Harms	2021
9	*Coffea bridsoniae*	Tree	EN	A.P. Davis & Mvungi	2021
10	*Englerodendron usambarense*	Tree	NT	Harms	2021
11	*Suregada lithoxyla*	Shrub	NT	(Pax & K. Hoffm.) Croizat	2021
12	*Isolona heinsenii*	Tree	VU	Engl. & Diels	2021
13	*Monanthotaxis trichantha*	Tree	VU	(Diels) Verdc.	2021
14	*Isoberlinia scheffleri*	Tree	VU	(Harms)Milne - Redhead	1975
15	*Allanblackia ulugurensis*	Tree	VU	Engl.	2021
16	*Polysphaeria braunii*	Tree	VU	K. Krause	1977

Major Habitat types

The updated checklist was recorded from diverse types of habitats that were common in MINAPA. These habitat types were unique in terms of species composition, each containing several species that did not belong to the other habitat type (Figure 4). While the old records were dominantly from grassland and woodland, the records in 2021 were from woodland and forest. Woodland was the richest habitat type in the area, with at least 60 species records. Only one species namely, Acalypha fruticose Forssk was recorded from all habitat types. Fourteen (14) species occurred from both forest and woodland; these include *Abrus fruticulosus* Wall. Ex-Wight & Arn., *Vachellia hockii (De Wild.) Seigler & Ebinger, Senegalia mellifera* (Vahl) Seigler & Ebinger, *Vachellia sieberiana* (DC.) Kyal. & Boatwr., *Acalypha neptunica* Müll. Arg., *Acalypha lanceolata* Willd, *Achyranthes aspera* L., *Allophylus africanus* P. Beauv., *Asparagus setaceus* (Kunth) Jessop, *Balanites aegyptica* (L.) Del, *Bauhinia petersiana* Bolle. None of the species was common in Forest and Bushland, and *Balamites aegyptiaca* occurred in both bushland and grassland. Shrubland and woodland share 9 species (Figure 4), including *Albizia anthelmintica* Brongn., *Albizia gumufera* (J. F Gmel) A. R. Sm, *Scleria schimperiana* Boeck, *Aristida adscensums* L., *and Barleria fulvostellata* C.B.CL

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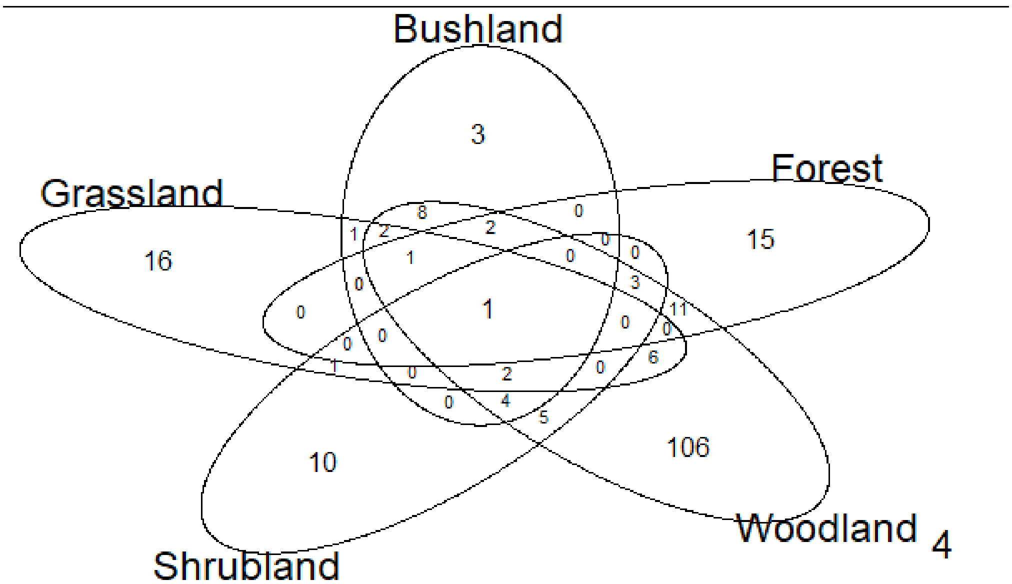

Fig. 4. Species composition across different habitat types in MINAPA Discussions

Information on flora resources helps in monitoring effects of climate and landcover changes happening overtime in many areas including protected areas (PAs) (Mengistu, 2005; Maria 2016; Lindsay et al. 2022). The updated floristic list of MINAPA used the currently accepted nomenclature names of families, genera, and species has shown the conservation value for MINAPA to sustainably supply forage, shelter, and save as a healthy water catchment resource for both human and wildlife species. This makes for a high need for conserving the high species diversity present in MINAPA and across Tanzania and the African region. Several of these species were found in the IUCN red list, indicating their threatened levels in terms of conservation or existence in their natural habitats and the high need for sustainable conservation strategies. Furthermore, this work has indicated the importance of MINAPA in preserving species endemism due to a significant number of endemic plants that are found in the Eastern Arc Mountains, noting the fact that several of the endemic species were recorded at the Malundwe Hill. The Malundwe Hill is currently known to be the only part of the Eastern Arc mountains which is completely protected due to being within borders of Mikumi National Park (Lovett and Norton 1989; Norton 1989). The information in this work will possibly contribute to improvement of management techniques of the vegetation resources as also appraised by (Thackway et al. 2007), and is a contribution to investment in scientific research and tourism (Buxton et al. 2021). The life-form spectrum presented corroborated the flora of arid areas worldwide (Chidumayo and Gumbo 2010; Timberlake, Chidumayo, and Sawadogo 2010), and specifically for Southern Tanzania (Bourlière and Hadley 1970). The predominance of trees, shrubs, shrub/tree, grasses and herbs is characteristic of savanna woodland where trees and shrubs form a light canopy (Belsky and Canham 1994; Frost 1996; Menaut & Lepage, 1995), indicating that the MINAPA is certainly in semi-arid conditions. The woodland preceding in terms of species richness, abundance and diversity, and the thickets having the lowest values of species richness, abundance and diversity.

The heterogeneous habitat types that form unique composition for each as seen in Figure 4, offer diversified plant species resources that are dominated by the grass family (Poaceae), along with other important families for the survival of the animals within (Bastian 2013; Tews et al. 2004). The family Poaceae is an ecologically important family of flowering plants for providing forage for many groups of herbivores (Carballo et al. 2019; Hodkinson 2018) whereas the Fabaceae is a diverse family that provides most of the browse species for animals. These are just few to cite for the critical role of the taxa that are available in MINAPA. Of great concern is the understanding that conserving the heterogeneous habitats needs fine scale prioritization (Benesperi et al. 2018; Harris, Jenkins, and Pimm 2005; Rouget 2003). This is always backed up by research information to avoid for example the loss of available resource as well as the endemic and threatened plant species and even plants required by animals with specialized needs.

Furthermore, the diverse additional records (ca. 173 species) made by the recent survey in 2021 to the previously obtained (ca. 778 species) in MINAPA signifies need for regular assessments of vegetation resources to monitor changes in floristic information. To meet specific requirement we urge surveys of vegetation resources should take a landscape approach to ensure a wider coverage of resources needed by the consumer group of animals (especially the herbivorous level) (DeGraaf and Healy 1992; Dennis 2012). Therefore, surveys are important for specific PAs and ecosystems. Regular vegetation surveys will save for a quick and reliable realization of the effects of the ongoing climatic variability worldwide, that cause habitat changes (Malhi et al. 2020; Thomas & Gillingham 2015). Furthermore, the regular vegetation studies will consequently help getting deep understanding of underrepresented taxa such as the monocotyledonous and pteridophytes because they have insufficient samples. The low samples were possibly due to poor road network to allow navigation especially in the wet seasons as also acknowledged by others (Rosell Pagès et al. 2016). The old records were dominantly from grassland and woodland, the records in 2021 were from woodland and forest, which supports the observed variation in species composition across the different surveys.

Conclusions and recommendations are missing

Monitoring of floral resources is critical for informed decisions on the conservation of wildlife in protected areas. This work has significantly improved our understanding of the flora of MINAPA. The study has made a vital contribution to the improvement of scientific research and management techniques under the ongoing changes in climatic conditions. Based on thsese results, we urge management authorities and researchers to make regular surveys to acertain the status of floral resources in our protected areas where reports are of the old taxonomic nomenclature.

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Table 6: An updated plant check list of Mikumi National Park

SN	Family	Species name	Life-Form	IUCN status	Endemism	Author	Record status
1	Acanthaceae	*Asystasia gangetica*	Herb			(L.) T. Anders	1960s-1990s
2	Acanthaceae	*Barleria fulvostellata*	Herb			C.B.CL	1960s-1990s
3	Acanthaceae	*Barleria grandicalyx*	Herb			Lindau	1960s-1990s
4	Acanthaceae	*Barleria tanzaniana*	Herb			(Brummitt & J. R. I. Wood) I. Darbysh.	1960s-1990s
5	Acanthaceae	*Blepharis affinis*	Herb			Lindau	1960s-1990s
6	Acanthaceae	*Blepharis involucrata*	Herb			Solms ex Schweinf.	1960s-1990s
7	Acanthaceae	*Blepharis maderaspatensis*	Herb			(L.) B. Heyne ex Roth	1960s-1990s
8	Acanthaceae	*Blepharis stuhlmannii*	Herb			Lindau	1960s-1990s
9	Acanthaceae	*Brillantaisia owariensis*	Herb			Beauverd	2021
10	Acanthaceae	*Crossandra puberula*	Herb			Klotzsch	1960s-1990s
11	Acanthaceae	*Crossandra subacaulis*	Herb			C.B.CL	1960s-1990s
12	Acanthaceae	*Dicliptera verticillata*	Herb			(Forssk) C. Chr.	1960s-1990s
13	Acanthaceae	*Dyschoriste trichocalyx sub-sp. verticillaris*	Herb			(C. B. Clarke) Vollesen	1960s-1990s
14	Acanthaceae	*Hygrophila schulli*	Herb			(Buch.-Ham.) M. R. Almeida & S. M. Almeida	1960s-1990s
15	Acanthaceae	*Hypoestes aristata*	Herb			(Vahl) Sol. ex Roem. & Schult.	1960s-1990s
16	Acanthaceae	*Hypoestes forskaolii*	Herb			(Vahl) Roem & Schult	1960s-1990s
17	Acanthaceae	*Hypoestes triflora*	Herb			Roem & Schult	1960s-1990s
18	Acanthaceae	*Isoglossa floribunda*	Herb			C. B. Clarke	1960s-1990s
19	Acanthaceae	*Justicia betonica*	Herb			L.	1960s-1990s
20	Acanthaceae	*Justicia nyassana*	Herb			Lindau	1960s-1990s
21	Acanthaceae	*Justicia scandens*	Herb			Vahl	1960s-1990s
22	Acanthaceae	*Justicia striata subsp. insularis*	Herb			(T. Anderson) J. K. Morton	1960s-1990s
23	Acanthaceae	*Mimulopsis solmsii*	Herb			Schweinf.	2021
24	Acanthaceae	*Monechma debile*	Herb			Nees	1960s-1990s
25	Acanthaceae	*Nelsonia canescens*	Herb			(Lam.) Spreng.	2021
26	Acanthaceae	*Phaulopsis imbricata*	Herb			(Forssk.) Sweet	2021
27	Acanthaceae	*Pseuderanthemum hildebrandtii*	Herb			Lindau	1960s-1990s
28	Acanthaceae	*Pseuderanthemum tunicatum*	Herb			(Afzel) Milne - Redhead	1960s-1990s
29	Acanthaceae	*Ruellia cordata*	Herb			Thunb	1960s-1990s
30	Acanthaceae	*Sclerochiton vogelii*	Herb			T.Anders	1960s-1990s
31	Acanthaceae	*Thunbergia alata*	Herb			Boj. Ex Sims	1960s-1990s
32	Acanthaceae	*Thunbergia heterochondros*	Herb			Hildbr. Napper	1960s-1990s
33	Adiantaceae	*Adiantum philippense*	Herb			L.	1960s-1990s
34	Adiantaceae	*Doryopteris concolor*	Herb			(Langsd.and Fisch) Kuhn	1960s-1990s

SN	Family	Species name	Life-Form	IUCN status	Endemism	Author	Record status
35	Aizoaceae	*Glinus Lotoides*	Herb			L.	1960s-1990s
36	Aizoaceae	*Paramollugo nudicaulis*	Herb			(Lam.) Thulin	1960s-1990s
37	Alismataceae	*Burnatia enneandra*	Herb			Michelli	1960s-1990s
38	Amaranthaceae	*Achyranthes aspera*	Herb			L.	1960s-1990s
39	Amaranthaceae	*Aerva lanata*	Herb			(L.) Schult.	1960s-1990s
40	Amaranthaceae	*Alternanthera pungens*	Herb			Kunth.	1960s-1990s
41	Amaranthaceae	*Alternanthera sessilis*	Herb			(L.) DC.	1960s-1990s
42	Amaranthaceae	*Amaranthus graecizans*	Herb			L.	1960s-1990s
43	Amaranthaceae	*Amaranthus hybridus*	Herb			L.	1960s-1990s
44	Amaranthaceae	*Amaranthus viridis*	Herb			L.	1960s-1990s
45	Amaranthaceae	*Celosia acroprosodes*	Herb			Hochst.	1960s-1990s
46	Amaranthaceae	*Celosia argentea*	Herb			L.	1960s-1990s
47	Amaranthaceae	*Celosia schweinfurthiana*	Herb			Schinz	1960s-1990s
48	Amaranthaceae	*Centemopsis kirkii*	Herb			(Hook f.) Schinz	1960s-1990s
49	Amaranthaceae	*Cyathula prostrata*	Herb			(L.) Blume	1960s-1990s
50	Amaranthaceae	*Gomphrena celosioides*	Herb			C. Mart.	1960s-1990s
51	Amaranthaceae	*Nothosaerva brachiata*	Herb			(L.) Wight	1960s-1990s
52	Amaranthaceae	*Psilotrichum elliotii*	Herb			Bak	1960s-1990s
53	Amaranthaceae	*Psilotrichum schimperi*	Herb			Engl.	1960s-1990s
54	Amaranthaceae	*Psilotrichum scleranthum*	Herb			Thunb	1960s-1990s
55	Amaranthaceae	*Pupalia lappacea*	Herb			(L.) A. Juss.	1960s-1990s
56	Amaryllidaceae	*Ammocharis tinneana*	Herb			(Kotschy & Peyr.) Mine - Red head	1960s-1990s
57	Amaryllidaceae	*Crinum kirkii*	Herb			Bak	1960s-1990s
58	Anacardiaceae	*Lannea humilis*	Tree			(Oliv.) Engl.	2021
59	Anacardiaceae	*Lannea schimperi*	Tree			(Hochst. ex A. Rich.) Engl.	2021
60	Anacardiaceae	*Lannea schweinfurthii*	Tree			(Engl.) Kokwaro	1960s-1990s
61	Anacardiaceae	*Ozoroa insignis*	Tree			Delile	2021
62	Anacardiaceae	*Sclerocarya birrea*	Tree			(A. Rich) Hochst	1960s-1990s
63	Anacardiaceae	*Sclerocarya birrea subsp. caffra*	Tree			(Sond.) Kokwaro	1960s-1990s
64	Anacardiaceae	*Searsia natalensis*	Tree			(Bernh. ex Krauss) F. A. Barkley	2021
65	Anacardiaceae	*Searsia pyroides*	Tree			(Burch.) Moffett	1960s-1990s
66	Anacardiaceae	*Sorindeia madagascariensis*	Tree			DC	1960s-1990s
67	Annonaceae	*Annona senegalensis*	Tree			Pers	1960s-1990s
68	Annonaceae	*Isolona heinsenii*	Tree	VU	Tanzania	Engl. & Diels	2021
69	Annonaceae	*Lettowianthus stellatus*	Tree			Diels	1960s-1990s
70	Annonaceae	*Monanthotaxis buchananii*	Tree			Diels	1960s-1990s
71	Annonaceae	*Monanthotaxis fornicata*	Tree			(Baill.) Verdc.	2021
72	Annonaceae	*Monanthotaxis trichantha*	Tree	VU	Tanzania	(Diels) Verdc.	2021
73	Annonaceae	*Sphaerocoryne gracilis*	Tree			(Oliv. ex Engl. & Diels) Verdc.	2021
74	Annonaceae	*Uvaria lucida*	Tree			Benth.	2021

SN	Family	Species name	Life-Form	IUCN status	Endemism	Author	Record status
75	Annonaceae	*Uvariodendron oligocarpum*	Tree	EN	Tanzania	Verdc.	2021
76	Annonaceae	*Uvariodendron pycnophyllum*	Tree	EN	Tanzania	(Diels) R. E. Fr.	2021
77	Annonaceae	*Uvariodendron usambarense*	Tree	EN	Tanzania	R. E. Fr.	2021
78	Annonaceae	*Xylopia arenaria*	Tree	VU		Engl.	2021
79	Annonaceae	*Xylopia parviflora*	Tree			(A. Rich.) Benth.	2021
80	Anthericaceae	*Chlorophytum cameronii*	Herb			(Baker) Kativu.	1960s-1990s
81	Anthericaceae	*Chlorophytum heynei*	Herb			Bak	1960s-1990s
82	Apiaceae	*Steganotaenia araliacea*	Shrub			Hochst.	2021
83	Apocynaceae	*Adenium obesum*	Shrub			(Forssk.) Roem. & Schult	1960s-1990s
84	Apocynaceae	*Adenium obesum subsp. multiflorum*	Shrub			(Klotzsch) G. D. Rowley	1960s-1990s
85	Apocynaceae	*Carvalhoa campanulata*	Shrub			K. Schum	1960s-1990s
86	Apocynaceae	*Diplorhynchus condylocarpon*	Shrub			(Muell. Arg) Pichon	1960s-1990s
87	Apocynaceae	*Funtumia africana*	Shrub			(Benth) Stapf	1960s-1990s
88	Apocynaceae	*Rauvolfia mombasiana*	Shrub			Stapf	2021
89	Apocynaceae	*Rauvolfia volkensii*	Shrub	VU		(K. Schum.) Stapf	2021
90	Apocynaceae	*Rauvolfia vomitoria*	Shrub			Afzel.	2021
91	Apocynaceae	*Saba florida*	Shrub			(Benth.) Bullock	1960s-1990s
92	Apocynaceae	*Saba comorensis*	Shrub			(Bojer) Pichon var	1960s-1990s
93	Apocynaceae	*Schizozygia coffaeoides*	Shrub			Baill.	1960s-1990s
94	Apocynaceae	*Secamone parvifolia*	Shrub			(Oliv) Bull	1960s-1990s
95	Apocynaceae	*Tabernaemontana ventricosa*	Shrub			Hochst. ex A. DC.	2021
96	Apocynaceae	*Voacanga africana*	Shrub			Stapf ex Scott Elliot	1960s-1990s
97	Araceae	*Amorphophallus goetzel*	Herb			(Engl.) N.E Br.	1960s-1990s
98	Araceae	*Culcasia falcifolia*	Herb			Engl.	1960s-1990s
99	Araceae	*Culcasia orientalis*	Herb			Mayo	2021
100	Araceae	*Gonatopus boivinii*	Herb			(Decne) Engl	1960s-1990s
101	Araceae	*Pistia stratiotes*	Herb			L.	1960s-1990s
102	Araceae	*Stylochiton natalensis*	Herb			Schott	1960s-1990s
103	Araliaceae	*Cussonia arborea*	Shrub			A.Rich.	1960s-1990s
104	Araliaceae	*Polyscias stuhlmannii*	Shrub	EN	Tanzania and Kenya	Harms	2021
105	Aristolochiaceae	*Aristolochia albida*	Herb			Duchartre	1960s-1990s
106	Asclepiadaceae	*Asplenium pumilum*	Herb			Sw.	1960s-1990s
107	Asclepiadaceae	*Ceropegia gigantea*	Herb			(N. E. Br.) Bruyns	1960s-1990s
108	Asclepiadaceae	*Kanahia laniflora*	Herb			(Forssk.) R. Br.	1960s-1990s
109	Asclepiadaceae	*Tacazzea apiculata*	Herb			Oliv.	1960s-1990s
110	Asparagaceae	*Asparagus aethiopicus*	Herb			Bak	1960s-1990s
111	Asparagaceae	*Asparagus africanus*	Herb			Lam.	2021
112	Asparagaceae	*Asparagus buchananii*	Herb			Bak	1960s-1990s
113	Asparagaceae	*Asparagus falcatus*	Herb			L.	2021
114	Asparagaceae	*Asparagus schroederi*	Herb			*Engl.*	1960s-1990s

SN	Family	Species name	Life-Form	IUCN status	Endemism	Author	Record status
115	Asparagaceae	*Asparagus setaceus*	Herb			(Kunth) Jessop	1960s-1990s
116	Asparagaceae	*Dracaena mannii*	Herb			Baker	2021
117	Asteraceae	*Acmella uliginosa*	Herb			(Sw.) Cass.	1960s-1990s
118	Asteraceae	*Ageratum conyzoides*	Herb			L.	1960s-1990s
119	Asteraceae	*Ananthura pteropoda*	Herb			(Oliv. & Hiern) H. Rob. & Skvarla	2021
120	Asteraceae	*Anaphalis subdecurrens*	Herb			(DC.) Gamble	1960s-1990s
121	Asteraceae	*Aspilia mosambicensis*	Herb			(Oliv.) Wild	1960s-1990s
122	Asteraceae	*Aspilia natalensis*	Herb			(Sond.) Wild	1960s-1990s
123	Asteraceae	*Baccharoides adoensis*	Herb			(Sch. Bip. ex Walp.) H. Rob.	1960s-1990s
124	Asteraceae	*Baccharoides anthelmintica*	Herb			(L.) Moench	1960s-1990s
125	Asteraceae	*Baccharoides lasiopus*	Herb			(O. Hoffm.) H. Rob.	2021
126	Asteraceae	*Bidens pilosa*	Herb			L.	1960s-1990s
127	Asteraceae	*Bidens schimperi*	Herb			Sch. Bip. ex Walp.	2021
128	Asteraceae	*Bidens taylorii*	Herb			(S. Moore) Sherff	1960s-1990s
129	Asteraceae	*Cyanthillium cinereum*	Herb			(L.) H. Rob.	1960s-1990s
130	Asteraceae	*Eclipta prostrata*	Herb			L.	1960s-1990s
131	Asteraceae	*Ecliptica alba*	Herb			Kuntze	1960s-1990s
132	Asteraceae	*Emilia javanica*	Herb			C.B. Rob	1960s-1990s
133	Asteraceae	*Emilia sonchifolia*	Herb			DC	1960s-1990s
134	Asteraceae	*Erigeron sumatrensis*	Herb			Retz.	1960s-1990s
135	Asteraceae	*Eriosema psoraleoides*	Herb			(Lam.) G.Don	2021
136	Asteraceae	*Erythrocephalum minus*	Herb			Oliv	1960s-1990s
137	Asteraceae	*Grangea maderaspatana*	Herb			Poir	1960s-1990s
138	Asteraceae	*Gymnanthemum auriculiferum*	Herb			(Hiern) Isawumi	2021
139	Asteraceae	*Gymnanthemum myrianthum*	Herb			(Hook. fil.) H. Rob.	2021
140	Asteraceae	*Hypericophyllum elatum*	Herb			N.E.Br	1960s-1990s
141	Asteraceae	*Laggera alata*	Herb			(D. Don) Sch. Bip. ex Oliv.	1960s-1990s
142	Asteraceae	*Launaea cornuta*	Herb			(Hochst, ex Oliv & Hiern) C.Jeffrey	1960s-1990s
143	Asteraceae	*Linzia glabra*	Herb			Steetz	1960s-1990s
144	Asteraceae	*Macledium sessiliflorum sub-sp. sessiliflorum*	Herb			Harv.	1960s-1990s
145	Asteraceae	*Microglossa pyrifolia*	Herb			Kuntze	1960s-1990s
146	Asteraceae	*Pegolettia senegalensis*	Herb			Cass	1960s-1990s
147	Asteraceae	*Pluchea dioscoridis*	Herb			DC	1960s-1990s
148	Asteraceae	*Pseudoconyza viscosa*	Herb			(Mill.) D' Arcy	1960s-1990s
149	Asteraceae	*Sphaeranthus africanus*	Herb			L.	1960s-1990s
150	Asteraceae	*Sphaeranthus kirkii*	Herb			Oliv. & Hiern	1960s-1990s
151	Asteraceae	*Sphaeranthus senegalensis*	Herb			DC.	1960s-1990s
152	Asteraceae	*Synedrella nodiflora*	Herb			(L.) Gaertn.	1960s-1990s

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153	Asteraceae	*Tridax procumbens*	Herb			L.	1960s-1990s
154	Asteraceae	*Vernonia galamensis*	Herb			(Cass.) Less.	2021
155	Asteraceae	*Vernonia shweinfurthii*	Herb			Oliv. & Hiern.	1960s-1990s
156	Asteraceae	*Vernonia stuhlmannii*	Herb			O.Hoffin	1960s-1990s
157	Asteraceae	*Vernoniastrum aemulans*	Herb			(Vatke) H. Rob.	1960s-1990s
158	Asteraceae	*Vernoniastrum latifolium*	Herb			(Steetz) H. Rob.	1960s-1990s
159	Balanitaceae	*Balanites aegyptiaca*	Tree			(L.) Del	1960s-1990s
160	Balanitaceae	*Balanites glabra*	Tree			Mildbr. & Schltr.	2021
161	Bignoniaceae	*Kigelia africana*	Tree			(Lam.) Benth.	1960s-1990s
162	Bignoniaceae	*Markhamia lutea*	Tree			(Benth.) K. Schum.	2021
163	Bignoniaceae	*Markhamia obtusifolia*	Shrub			(Bak) Sprague	1960s-1990s
164	Bignoniaceae	*Markhamia zanzibarica*	Shrub			(Bojer ex DC.) K. Schum.	1960s-1990s
165	Bignoniaceae	*Stereospermum kunthianum*	Tree			Cham	1960s-1990s
166	Bombaceae	*Adansonia digitata*	Tree			L.	1960s-1990s
167	Boraginaceae	*Bourreria petiolaris*	Shrub			(Lam.) Thulin	1960s-1990s
168	Boraginaceae	*Cordia africana*	Tree			Lam.	1960s-1990s
169	Boraginaceae	*Cordia monoica*	Tree			Roxb.	1960s-1990s
170	Boraginaceae	*Cordia monoica subsp. monoica*	Tree			R. Br. ex DC.	1960s-1990s
171	Boraginaceae	*Ehretia amoena*	Tree			KI	1960s-1990s
172	Boraginaceae	*Euploca strigosa*	Herb			(Willd.) Diane & Hilger	1960s-1990s
173	Boraginaceae	*Heliotropium indicum*	Herb			L.	1960s-1990s
174	Boraginaceae	*Heliotropium supinum*	Herb			L.	1960s-1990s
175	Boraginaceae	*Trichodesma zeylanicum*	Herb			(Burm.f.) R.Br.	1960s-1990s
176	Burseaceae	*Commiphora africana*	Tree			(A. Rich) Engl	1960s-1990s
177	Burseaceae	*Commiphora edulis subsp. boiviniana*	Tree			(Engl.) Gillett	1960s-1990s
178	Burseaceae	*Commiphora pteleifolia*	Tree			Engl.	1960s-1990s
179	Cactaceae	*Rhipsalis parasitica subsp. parasitica*	Tree			(J.Mill.) Stearn.	1960s-1990s
180	Caesalpinioideae	*Afzelia quanzensis*	Tree			Welw	1960s-1990s
181	Caesalpinioideae	*Bauhinia petersiana*	Tree			Bolle	2021
182	Caesalpinioideae	*Bauhinia tomentosa*	Tree			L.	1960s-1990s
183	Caesalpinioideae	*Brachystegia allenii*	Tree			Hutch. & Burtt Davy	2021
184	Caesalpinioideae	*Brachystegia boehmii*	Tree			Taub	1960s-1990s
185	Caesalpinioideae	*Brachystegia bussei*	Tree			Harms	1960s-1990s
186	Caesalpinioideae	*Brachystegia floribunda*	Tree			Benth.	2021
187	Caesalpinioideae	*Brachystegia longifolia*	Tree			Benth	1960s-1990s
188	Caesalpinioideae	*Brachystegia manga*	Tree			De Wild	1960s-1990s
189	Caesalpinioideae	*Brachystegia spiciformis*	Tree			Benth	1960s-1990s
190	Caesalpinioideae	*Brachystegia stipulata*	Tree			De Wild.	2021
191	Caesalpinioideae	*Brachystegia tamarindoides subsp. microphylla*	Tree			(Harms) Chikuni	1960s-1990s

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192	Caesalpinioideae	*Burkea africana*	Tree			Hook	1960s-1990s
193	Caesalpinioideae	*Cassia abbreviata*	Tree			Oliv.	1960s-1990s
194	Caesalpinioideae	*Chamaecrista absus*	Herb			(L.) H.S.Irwin & Barneby	1960s-1990s
195	Caesalpinioideae	*Chamaecrista grantii*	Tree			(Oliv.) Standl.	1960s-1990s
196	Caesalpinioideae	*Chamaecrista mimosoides*	Herb			(L.) Greene	1960s-1990s
197	Caesalpinioideae	*Chamaecrista stricta*	Tree			E.Mey.	1960s-1990s
198	Caesalpinioideae	*Cordyla africana*	Tree			Lour	1960s-1990s
199	Caesalpinioideae	*Cryptosepalum maraviense*	Shrub			Oliv.	2021
200	Caesalpinioideae	*Dialium holtzii*	Tree			Harms	2021
201	Caesalpinioideae	*Englerodendron usambarense*	Tree	NT	Tanzania	Harms	2021
202	Caesalpinioideae	*Isoberlinia scheffleri*	Tree	VU	Tanzania	(Harms)Milne - Redhead	1960s-1990s
203	Caesalpinioideae	*Julbernardia globiflora*	Tree			(Benth) Troupin	1960s-1990s
204	Caesalpinioideae	*Mezoneuron angolense*	Tree			Welw. ex Oliv.	2021
205	Caesalpinioideae	*Piliostigma thonningii*	Tree			(K.Schum.) Milne - Redhead	1960s-1990s
206	Caesalpinioideae	*Senna auriculata*	Shrub			(L.) Roxb.	1960s-1990s
207	Caesalpinioideae	*Senna hirsuta*	Herb			(L.) H.S.Irwin & Barneby	1960s-1990s
208	Caesalpinioideae	*Senna obtusifolia*	Herb			(L.) H.S.Irwin & Barneby	1960s-1990s
209	Caesalpinioideae	*Senna siamea*	Tree			(Lam.) H.S.Irwin & Barneby	1960s-1990s
210	Caesalpinioideae	*Senna singueana*	Tree			(Delile) Lock	1960s-1990s
211	Caesalpinioideae	*Tamarindus indica*	Tree			L.	1960s-1990s
212	Caesalpinioideae	*Tylosema fassoglensis*	Herb			(Schweinf.) Torre & Hillc.	1960s-1990s
213	Caesalpinioideae	*Vachellia kirkii*	Tree			(Oliv.) Kyal. & Boatwr.	2021
214	Caesalpinioideae	*Zenkerella perplexa*	Tree	CR	Tanzania	Temu	2021
215	Cannabaceae	*Trema orientalis*	Tree			(L.) Blume	2021
216	Capparidaceae	*Boscia salicifolia*	Tree			Oliv	1960s-1990s
217	Capparidaceae	*Capparis tomentosa*	Tree			Lam	1960s-1990s
218	Capparidaceae	*Corynandra simplicifolia*	Herb			(Cambess.) Roalson	1960s-1990s
219	Capparidaceae	*Gynandropsis gynandra*	Herb			(L.) Briq.	1960s-1990s
220	Capparidaceae	*Maerua angolensis*	Shrub			DC	1960s-1990s
221	Capparidaceae	*Maerua edulis*	Herb			(Gilg. & Ren) De Wolf	1960s-1990s
222	Capparidaceae	*Maerua grantii*	Shrub			Oliv	1960s-1990s
223	Capparidaceae	*Sieruela hirta*	Herb			(Klotzsch) Roalson & J. C. Hall	1960s-1990s
224	Capparidaceae	*Thilachium africanum*	Shrub			Lour	1960s-1990s
225	Caryophyllaceae	*Polycarpaea eriantha*	Herb			A.Rich. Var eriantha	1960s-1990s
226	Celastraceae	*Catha edulis*	Shrub			Forssk.	2021

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227	Celastraceae	*Elaeodendron buchananii*	Tree			(Loes) Loes	1960s-1990s
228	Celastraceae	*Gymnosporia acuminata*	Tree			(L. fil.) Szyszyl.	1960s-1990s
229	Celastraceae	*Gymnosporia senegalensis*	Tree			(Lam.) Loes.	1960s-1990s
230	Celastraceae	*Gymnosporia undata*	Tree			(Thunb.) Szyszyl.	1960s-1990s
231	Celastraceae	*Mystroxylon aethiopicum*	Tree			(Thunb.) Loes.	2021
232	Celastraceae	*Salacia madagascariensis*	liana			(Lam.) DC.	2021
233	Chrysobalanaceae	*Parinari excelsa*	Tree			Sabine	1960s-1990s
234	Clusiaceae	*Garcinia buchananii*	Tree			Baker	2021
235	Colchicaceae	*Gloriosa superba*	Herb			L.	1960s-1990s
236	Combretaceae	*Combretum adenogonium*	Tree			Steud. ex A. Rich.	2021
237	Combretaceae	*Combretum apiculatum*	Tree			Sond.	2021
238	Combretaceae	*Combretum collinum*	Tree			Fresen(Engl) Okafor	1960s-1990s
239	Combretaceae	*Combretum hereroense*	Tree			Schinz	1960s-1990s
240	Combretaceae	*Combretum molle*	Tree			G.Don	1960s-1990s
241	Combretaceae	*Combretum mossambicense*	Tree			(Kl) Engl	1960s-1990s
242	Combretaceae	*Combretum paniculatum*	Tree			Vent	1960s-1990s
243	Combretaceae	*Combretum pentagonum*	Tree			Lass.	2021
244	Combretaceae	*Combretum zeyheri*	Tree			Sond	1960s-1990s
245	Combretaceae	*Terminalia brownii*	Tree			Fresen	1960s-1990s
246	Combretaceae	*Terminalia kaiserana*	Tree			F.Hoff	1960s-1990s
247	Combretaceae	*Terminalia kilimandscharica*	Tree			Engl	1960s-1990s
248	Combretaceae	*Terminalia mollis*	Tree			Laws	1960s-1990s
249	Combretaceae	*Terminalia myrtifolia*	Tree			(M. A. Lawson) Gere & Boatwr.	1960s-1990s
250	Combretaceae	*Terminalia sambesiaca*	Tree			Engl. & Diels	1960s-1990s
251	Combretaceae	*Terminalia sericea*	Tree			DC	1960s-1990s
252	Combretaceae	*Terminalia spinosa*	Tree			Engl	1960s-1990s
253	Combretaceae	*Terminalia stenostachya*	Tree			Engl	1960s-1990s
254	Combretaceae	*Terminalia trichopoda*	Tree			Diels	1960s-1990s
255	Commelinaceae	*Aneilema aequinoctiale*	Herb			(P.Beauv.) G.Don	2021
256	Commelinaceae	*Aneilema pedunculosum*	Herb			C.B.CL.	1960s-1990s
257	Commelinaceae	*Commelina benghalensis*	Herb			L.	1960s-1990s
258	Commelinaceae	*Commelina bracteosa var. lagosensis*	Herb			(C.B.Clarke) Faden	1960s-1990s
259	Commelinaceae	*Commelina diffusa*	Herb			Burm.f.	1960s-1990s
260	Commelinaceae	*Commelina erecta*	Herb			Lssp.erecta	1960s-1990s
261	Commelinaceae	*Commelina foliacea*	Herb			Chiov.	1960s-1990s
262	Commelinaceae	*Commelina latifolia*	Herb			A.Rich.	1960s-1990s
263	Commelinaceae	*Commelina subulata*	Herb			Roth	1960s-1990s
264	Commelinaceae	*Murdannia simplex*	Herb			(Vahl.) Brenan	1960s-1990s
265	Connaraceae	*Agelaea pentagyna*	Tree			(Lam.) Baill.	1960s-1990s
266	Connaraceae	*Rourea orientalis*	Shrub			Baill.	1960s-1990s
267	Connaraceae	*Rourea thomsonii*	Tree			(Baker) Jongkind	2021

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268	Convolvulaceae	*Evolvulus alsinoides*	Herb			(L.) L.	1960s-1990s
269	Convolvulaceae	*Ipomoea aquatica*	Herb			Forssk	1960s-1990s
270	Convolvulaceae	*Ipomoea batatas*	Herb			(L.) Lam.	1960s-1990s
271	Convolvulaceae	*Ipomoea coptica*	Herb			(L.) Roem. & Schult.	1960s-1990s
272	Convolvulaceae	*Ipomoea crassipes*	Herb			Hook	1960s-1990s
273	Convolvulaceae	*Ipomoea crepidiformis*	Herb			Hall.f	1960s-1990s
274	Convolvulaceae	*Ipomoea eriocarpa*	Herb			R.Br.	1960s-1990s
275	Convolvulaceae	*Ipomoea heterotricha*	Herb			F. Didr	1960s-1990s
276	Convolvulaceae	*Ipomoea involucrata*	Herb			Beauv	1960s-1990s
277	Convolvulaceae	*Ipomoea lapathifolia*	Herb			Hall.f	1960s-1990s
278	Convolvulaceae	*Ipomoea malvacea*	Herb			(Klotzsch) J. R. I. Wood & Scotland	1960s-1990s
279	Convolvulaceae	*Ipomoea mombassana*	Herb			Vatke	1960s-1990s
280	Convolvulaceae	*Ipomoea obscura*	Herb			(L.) Ker - Gam	1960s-1990s
281	Convolvulaceae	*Ipomoea owariensis*	Herb			P. Beauv.	1960s-1990s
282	Convolvulaceae	*Ipomoea rubens*	Herb			Choicy	1960s-1990s
283	Convolvulaceae	*Ipomoea sinensis*	Herb			(Desr) Choisy	1960s-1990s
284	Convolvulaceae	*Ipomoea tenuipes*	Herb			Verde	1960s-1990s
285	Convolvulaceae	*Ipomoea venosa*	Herb			(Desr) Roem	1960s-1990s
286	Convolvulaceae	*Jacquemontia paniculata*	Herb			(Bum.f) Hall f.	1960s-1990s
287	Convolvulaceae	*Jacquemontia tamnifolia*	Herb			(L.) Griseb	1960s-1990s
288	Convolvulaceae	*Merremia hederacea*	Herb			(Bum.f) Hall f.	1960s-1990s
289	Convolvulaceae	*Merremia palmata*	Herb			Hall.f	1960s-1990s
290	Convolvulaceae	*Xenostegia pinnata*	Herb			(Hochst. ex Choisy) A. R. Simões & Staples	1960s-1990s
291	Crassulaceae	*Kalanchoe integra*	Herb			(Med) Kuntze	1960s-1990s
292	Cruciferae	*Brassica juncea*	Herb			(L.) Czern	1960s-1990s
293	Cruciferae	*Rorippa micrantha*	Herb			(Roth) Jonsell	1960s-1990s
294	Cucurbitaceae	*Blastania cerasiformis*	Herb			(Stocks) A. Meeuse	1960s-1990s
295	Cucurbitaceae	*Coccinia grandis*	Herb			(L.) Voigt	1960s-1990s
296	Cucurbitaceae	*Cucumis hirsutus*	Herb			Sond	1960s-1990s
297	Cucurbitaceae	*Cucumis maderaspatanus*	Herb			L.	1960s-1990s
298	Cucurbitaceae	*Cucumis melo*	Herb			L.	1960s-1990s
299	Cucurbitaceae	*Cucumis metuliferus*	Herb			Nand	1960s-1990s
300	Cucurbitaceae	*Cucumis sacleuxii*	Herb			Paik	1960s-1990s
301	Cucurbitaceae	*Lagenaria sphaerica*	Herb			(Sond) Nand	1960s-1990s
302	Cucurbitaceae	*Momordica anigosantha*	Herb			Gilg	1960s-1990s
303	Cucurbitaceae	*Zehneria scabra*	Herb			(L.f) Sond	1960s-1990s
304	Cucurbitaceae	*Zehneria thwaitesii*	Herb			(Schweinf.) C.Jeffrey	1960s-1990s
305	Cyperaceae	*Bulbostylis hispidula*	Sedge			(Vahl) R.W.Haines	1960s-1990s
306	Cyperaceae	*Bulbostylis pusilla*	Sedge			(A.Rich.) C.B.CL.R.Heines	1960s-1990s

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307	Cyperaceae	*Cyperus alternifolius*	Sedge			L.	1960s-1990s
308	Cyperaceae	*Cyperus amabilis*	Sedge			Vahl	1960s-1990s
309	Cyperaceae	*Cyperus articulatus*	Sedge			L.	1960s-1990s
310	Cyperaceae	*Cyperus ascocapensis*	Sedge			Bauters	1960s-1990s
311	Cyperaceae	*Cyperus bulbipes*	Sedge			Mattf. & Kük.	1960s-1990s
312	Cyperaceae	*Cyperus cancellatus*	Sedge			Ridley	1960s-1990s
313	Cyperaceae	*Cyperus comosipes*	Sedge			Mattf.and Kuk	1960s-1990s
314	Cyperaceae	*Cyperus compressus*	Sedge			L.	1960s-1990s
315	Cyperaceae	*Cyperus cyperoides*	Sedge			(L.) (Kunth) K.Lye	1960s-1990s
316	Cyperaceae	*Cyperus difformis*	Sedge			L.	1960s-1990s
317	Cyperaceae	*Cyperus distans*	Sedge			L.f.	1960s-1990s
318	Cyperaceae	*Cyperus dubius*	Sedge			Rott.	1960s-1990s
319	Cyperaceae	*Cyperus erectus*	Sedge			(Schumach.) Mattf. & Kük.	2021
320	Cyperaceae	*Cyperus exaltatus*	Sedge			Retz.	1960s-1990s
321	Cyperaceae	*Cyperus ferrugineoviridis*	Sedge			(C.B.Cl.) Kuk.	1960s-1990s
322	Cyperaceae	*Cyperus hemisphaericus*	Sedge			Boeck	1960s-1990s
323	Cyperaceae	*Cyperus imbricatus*	Sedge			Retz.	2021
324	Cyperaceae	*Cyperus iria*	Sedge			L.	1960s-1990s
325	Cyperaceae	*Cyperus macrostachyos*	Sedge			Lam.	1960s-1990s
326	Cyperaceae	*Cyperus maculatus*	Sedge			Boeck	1960s-1990s
327	Cyperaceae	*Cyperus mollipes*	Sedge			(C.B.Clarke) K.Schum.	1960s-1990s
328	Cyperaceae	*Cyperus niveus*	Sedge			Retz var. niveus	1960s-1990s
329	Cyperaceae	*Cyperus pumilus*	Sedge			L.var.patens (Vahl) Kuk.	1960s-1990s
330	Cyperaceae	*Cyperus renschii*	Sedge			Boeck.var.renschii	1960s-1990s
331	Cyperaceae	*Cyperus rotundus*	Sedge			(Rott.) Kuh.	1960s-1990s
332	Cyperaceae	*Cyperus squarrosus*	Sedge			L.	1960s-1990s
333	Cyperaceae	*Cyperus tenuispica*	Sedge			Steud.	1960s-1990s
334	Cyperaceae	*Eleocharis acutangula*	Sedge			(Roxb.) Schult.	1960s-1990s
335	Cyperaceae	*Fimbristylis barteri*	Sedge			Boeckeler	1960s-1990s
336	Cyperaceae	*Fimbristylis bisumbellata*	Sedge			(Forsk.) Buf.	1960s-1990s
337	Cyperaceae	*Fimbristylis microcarya var. microcarya*	Sedge			Boeckeler	1960s-1990s
338	Cyperaceae	*Fuirena ciliaris*	Sedge			(L.)Roxb	1960s-1990s
339	Cyperaceae	*Schoenoplectiella articulata*	Sedge			(L.) Lye	1960s-1990s
340	Cyperaceae	*Schoenoplectiella juncea*	Sedge			(Willd.) Lye	1960s-1990s
341	Cyperaceae	*Schoenoplectiella lateriflora*	Sedge			(J.F.Gmel.) Lye	1960s-1990s
342	Cyperaceae	*Schoenoplectiella senegalensis*	Sedge			(Steud.) Lye	1960s-1990s
343	Cyperaceae	*Scirpus aureglumis*	Sedge			Hooper	1960s-1990s
344	Cyperaceae	*Scirpus jacobii*	Sedge			C. E.C. Pischer	1960s-1990s
345	Cyperaceae	*Scleria foliosa*	Sedge			A.Rich.	1960s-1990s
346	Cyperaceae	*Scleria lithosperma*	Sedge			(L.)Sw.	1960s-1990s

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347	Cyperaceae	*Scleria schimperiana*	Sedge			Boeck	1960s-1990s
348	Dennstaedtiaceae	*Pteridium aquilinum*	Herb			(L.) Kuhn	2021
349	Dichapetalaceae	*Dichapetalum stuhlmannii*	liana			Engl.	2021
350	Dioscoreaceae	*Dioscorea sansibarensis*	Herb			Pax	1960s-1990s
351	Draceanaceae	*Dracaena laxissima*	Herb			Engl.	1960s-1990s
352	Draceanaceae	*Dracaena usambarensis*	Herb			Engl.	1960s-1990s
353	Ebenaceae	*Diospyros amaniensis*	Tree	VU	Kenya and Tanzania	Gurke	1960s-1990s
354	Ebenaceae	*Diospyros kabuyeana*	Tree			F.White	2021
355	Ebenaceae	*Diospyros kirkii*	Tree			Hiern	1960s-1990s
356	Ebenaceae	*Diospyros loureiroana*	Tree			G.Don	2021
357	Ebenaceae	*Diospyros mespiliformis*	Tree			DC	1960s-1990s
358	Ebenaceae	*Diospyros zombensis*	Tree			(B.L.Burtt) F.White	1960s-1990s
359	Erythroxylaceae	*Erythroxylum emarginatum*	Shrub			Thonn	1960s-1990s
360	Erythroxylaceae	*Pseudopus apodus*	Shrub			(Pallas, 1775)	2021
361	Euphorbiaceae	*Acalypha ciliata*	Herb			Forssk	1960s-1990s
362	Euphorbiaceae	*Acalypha fruticosa*	Herb			Forssk	1960s-1990s
363	Euphorbiaceae	*Acalypha indica*	Herb			L.	1960s-1990s
364	Euphorbiaceae	*Acalypha lanceolata*	Herb			Willd	1960s-1990s
365	Euphorbiaceae	*Acalypha neptunica*	Shrub			Müll.Arg.	2021
366	Euphorbiaceae	*Acalypha ornata*	Herb			A.Rich	1960s-1990s
367	Euphorbiaceae	*Acalypha petiolaris*	Herb			Hochst.	1960s-1990s
368	Euphorbiaceae	*Alchornea laxiflora*	Tree			(Benth) Pax & Hofffin	1960s-1990s
369	Euphorbiaceae	*Antidesma membranaceum*	Tree			Muell. Arg	1960s-1990s
370	Euphorbiaceae	*Antidesma venosum*	Tree			Thul	1960s-1990s
371	Euphorbiaceae	*Antidesma vogelianum*	Tree			Muell. Arg	1960s-1990s
372	Euphorbiaceae	*Bridelia cathartica*	Shrub			Bertol.f	1960s-1990s
373	Euphorbiaceae	*Bridelia micrantha*	Shrub			(Hochst.) Baill.	2021
374	Euphorbiaceae	*Caperonia stuhlmannii*	Herb			Pax	1960s-1990s
375	Euphorbiaceae	*Cleistanthus schlechteri*	Tree			(Pax) Hutch.	2021
376	Euphorbiaceae	*Croton dichogamus*	Shrub			Pax	1960s-1990s
377	Euphorbiaceae	*Dalechampia scandens*	Herb			L	1960s-1990s
378	Euphorbiaceae	*Drypetes reticulata*	Tree			Pax	1960s-1990s
379	Euphorbiaceae	*Drypetes usambarica*	Tree			(Pax) Hutch	1960s-1990s
380	Euphorbiaceae	*Erythrococca kirkii*	Shrub			(Muell. Arg) Prain	1960s-1990s
381	Euphorbiaceae	*Euphorbia candelabrum*	Tree			Kl	1960s-1990s
382	Euphorbiaceae	*Euphorbia hirta*	Herb			L	1960s-1990s
383	Euphorbiaceae	*Euphorbia hyssopifolia*	Herb			L	1960s-1990s
384	Euphorbiaceae	*Euphorbia prostrata*	Herb	CR	Tanzania	Ait	1960s-1990s
385	Euphorbiaceae	*Euphorbia systyloides*	Herb			Pax	1960s-1990s
386	Euphorbiaceae	*Flueggea virosa*	Shrub			(Willd.) Voigt.	1960s-1990s
387	Euphorbiaceae	*Hymenocardia acida*	Tree			Thul	1960s-1990s
388	Euphorbiaceae	*Macaranga kilimandscharica*	Tree			Pax	2021

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389	Euphorbiaceae	*Maprounea africana*	Shrub			F.Muell	1960s-1990s
390	Euphorbiaceae	*Margaritaria discoidea*	Tree			(Baill.) G.L.Webster	2021
391	Euphorbiaceae	*Phyllanthus amarus*	Herb			K.Schum & Thonn	1960s-1990s
392	Euphorbiaceae	*Phyllanthus sepialis*	Shrub			Muell.Arg	1960s-1990s
393	Euphorbiaceae	*Phyllanthus welwitschianus*	Shrub			Muell. Arg (Hutch) A.R.Smith	1960s-1990s
394	Euphorbiaceae	*Pseudolachnostylis maprouneifolia*	Tree			Pax	1960s-1990s
395	Euphorbiaceae	*Shirakiopsis elliptica*	Tree			(Hochst.) Esser	2021
396	Euphorbiaceae	*Spirostachys africana*	Tree			Sond	1960s-1990s
397	Euphorbiaceae	*Suregada lithoxyla*	Shrub	NT	Tanzania	(Pax & K.Hoffm.) Croizat	2021
398	Euphorbiaceae	*Thecacoris spathulifolia var. spathulifolia*	Tree			Pax	1960s-1990s
399	Euphorbiaceae	*Tragia adenanthera*	Climber			Baill.	2021
400	Euphorbiaceae	*Tragia furialis*	Shrub			Bojer	1960s-1990s
401	Euphorbiaceae	*Tragia hildebrandtii*	Herb			Muell.Arg	1960s-1990s
402	Flacourtiaceae	*Casearia battiscombei*	Tree			R. E. Fr.	2021
403	Flacourtiaceae	*Dovyalis abyssinica*	Tree			(Rich.) Warb.	2021
404	Flacourtiaceae	*Dovyalis macrocalyx*	Tree			(Oliv) Warb	1960s-1990s
405	Flacourtiaceae	*Flacourtia indica*	Tree			(Burm. fil.) Merr.	2021
406	Flacourtiaceae	*Lindackeria bukobensis*	Tree			Gilg	1960s-1990s
407	Flacourtiaceae	*Oncoba spinosa*	Tree			Forssk	1960s-1990s
408	Flacourtiaceae	*Rawsonia lucida*	Tree			Harv. & Sond.	1960s-1990s
409	Flacourtiaceae	*Xylotheca tettensis*	Tree			(Kl) Gilg	1960s-1990s
410	Flagellariaceae	*Flagellaria guineensis*	Herb			Schumach.	2021
411	Gentinaceae	*Canscora diffusa*	Herb			(Vahl.) Roem & Schult	1960s-1990s
412	Gentinaceae	*Enicostema axillare*	Herb			(Lam) A.Rayn	1960s-1990s
413	Gentinaceae	*Exacum quinquenervium*	Herb			Griseb	1960s-1990s
414	Guttiferae	*Allanblackia stuhlmannii*	Tree			(Engl.) Engl.	2021
415	Guttiferae	*Allanblackia ulugurensis*	Tree	VU	Tanzania	Engl.	2021
416	Guttiferae	*Garcinia huillensis*	Tree			Welw. Ex. Oliv	1960s-1990s
417	Guttiferae	*Garcinia volkensii*	Tree			Engl.	2021
418	Guttiferae	*Psorospermum febrifugum*	Tree			Spach	1960s-1990s
419	Hyacinthaceae	*Drimia altissima*	Herb			(L.f.) Ker Gawl.	1960s-1990s
420	Hydnoraceae	*Hydnora abyssinica*	Herb			Shweinf	1960s-1990s
421	Hydrocharitaceae	*Lagarosiphon muscoides*	Herb			Harvey	1960s-1990s
422	Hydrocharitaceae	*Ottelia ulvifolia*	Herb			(Planch) Walp.	1960s-1990s
423	Hypoxidaceae	*Hypoxis angustifolia*	Herb			Lam	1960s-1990s
424	Icacinaceae	*Apodytes dimidiata*	Tree			E. Mey. ex Arn.	2021
425	Icacinaceae	*Dasylepis integra*	Tree			Warb. ex Engl.	2021
426	Icacinaceae	*Pyrenacantha kaurabassana*	Herb			Baill	1960s-1990s
427	Icacinaceae	*Rhaphiostylis beninensis*	Shrub			(Planch) Benth	1960s-1990s

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428	Iridaceae	*Crocosmia aurea*	Herb			Planch	1960s-1990s
429	Iridaceae	*Dietes iridioides*	Herb			(L.) Sweet.	1960s-1990s
430	Iridaceae	*Gladiolus dalenii subsp. dalenii*	Herb			Reinw. ex Hook.	1960s-1990s
431	Labiatae	*Basilicum polystachyon*	Herb			(L) Moenth	1960s-1990s
432	Labiatae	*Coleus rhodesianum*	Herb			(N.E.Br.) A.J.Paton	1960s-1990s
433	Labiatae	*Coleus scruposus*	Herb			A.J.Paton	2021
434	Labiatae	*Equilabium flaccidum*	Herb			(Vatke) Mwany. & A.J.Paton	1960s-1990s
435	Labiatae	*Equilabium vesiculare*	Herb			(A.J.Paton) Mwany. & A.J.Paton	2021
436	Labiatae	*Haumaniastrum villosum*	Herb			(Benth.) A.J.Paton	1960s-1990s
437	Labiatae	*Hoslundia opposita*	Herb			Vahl	1960s-1990s
438	Labiatae	*Leonotis nepetifolia*	Herb			R.Br.	1960s-1990s
439	Labiatae	*Leucas deflexa*	Herb			Hook.f.	2021
440	Labiatae	*Leucas glabrata*	Herb			(Vahl) Sm.	1960s-1990s
441	Labiatae	*Leucas martinicensis*	Herb			(Jacq) R.Br	1960s-1990s
442	Labiatae	*Leucas nyassae*	Herb			Gurke	1960s-1990s
443	Labiatae	*Mesosphaerum pectinatum*	Herb			(L.) Kuntze	1960s-1990s
444	Labiatae	*Mesosphaerum suaveolens*	Herb			(L.) Kuntze	1960s-1990s
445	Labiatae	*Ocimum basilicum*	Herb			L.	1960s-1990s
446	Labiatae	*Ocimum gratissimum*	Herb			L.	2021
447	Labiatae	*Ocimum gratissimum sub-sp. gratissimum*	Herb			Willd.	1960s-1990s
448	Labiatae	*Ocimum obovatum*	Herb			E.Mey. ex Benth.	1960s-1990s
449	Labiatae	*Orthosiphon parvifolius*	Herb			Vatke	1960s-1990s
450	Labiatae	*Orthosiphon rubicundus*	Herb			Benth	1960s-1990s
451	Labiatae	*Orthosiphon thymiflorus*	Herb			(Roth) Sleesen	1960s-1990s
452	Lauraceae	*Beilschmiedia kweo*	Tree			(Mildbr.) Robyns & R. Wilczek	2021
453	Lemnaceae	*Lemna perpusilla*	Herb			Torr	1960s-1990s
454	Lentibulariaceae	*Utricularia stellaris*	Herb	VU		L.f.	1960s-1990s
455	Linaceae	*Hugonia castaneifolia*	Tree			Engl	1960s-1990s
456	Loganiaceae	*Strychnos henningsii*	Tree			Gilg	1960s-1990s
457	Loganiaceae	*Strychnos madagascariensis*	Tree			Poir.	1960s-1990s
458	Loganiaceae	*Strychnos potatorum*	Tree			L. fil.	2021
459	Loganiaceae	*Strychnos spinosa*	Tree			Lam	1960s-1990s
460	Loganiaceae	*Strychnos xylophylla*	Shrub	EN		Gilg	2021
461	Loranthaceae	*Englerina muerensis*	Shrub			Engl	1960s-1990s
462	Loranthaceae	*Erianthemum lindense*	Shrub	VU	Kenya and Tanzania	(Sprague) Danser	1960s-1990s
463	Loranthaceae	*Oncocalyx fischeri*	Shrub			(Engl.) M. G. Gilbert	1960s-1990s
464	Loranthaceae	*Phragmanthera berliniicola*	Shrub			Engl	1960s-1990s
465	Loranthaceae	*Plicosepalus curviflorus*	Shrub			(Benth)	1960s-1990s
466	Loranthaceae	*Spragueanella rhamnifolia*	Shrub			(Engl.) Balle	1960s-1990s

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467	Loranthaceae	*Taxillus remota*	Shrub			(Bak. & Sprague) Wiens	1960s-1990s
468	Lythraceae	*Ammannia auriculata*	Herb			Willd	1960s-1990s
469	Malvaceae	*Abutilon grandiflorum*	Herb			G.Don	1960s-1990s
470	Malvaceae	*Abutilon guineense*	Herb			(K.Schum) Bak.f.	1960s-1990s
471	Malvaceae	*Abutilon mauritianum*	Herb			(Jacq) Medic	1960s-1990s
472	Malvaceae	*Cola discoglypremnophylla*	Herb	EN	Tanzania	Brenan & A. P. D. Jones	2021
473	Malvaceae	*Hibiscus articulatus*	Herb			Hochs ex A. Rich	1960s-1990s
474	Malvaceae	*Hibiscus cannabinus*	Herb			L.	1960s-1990s
475	Malvaceae	*Hibiscus migeodii*	Herb			Exell	1960s-1990s
476	Malvaceae	*Hibiscus physaloides*	Herb			Guill	1960s-1990s
477	Malvaceae	*Hibiscus purpureus*	Herb			Forssk.	1960s-1990s
478	Malvaceae	*Hibiscus shirensis*	Herb			Sprague & Hutch	1960s-1990s
479	Malvaceae	*Hibiscus surattensis*	Herb			L	1960s-1990s
480	Malvaceae	*Hibiscus vitifolius*	Herb			L	1960s-1990s
481	Malvaceae	*Malvastrum coromandelianum*	Herb			(L.) Garcke	1960s-1990s
482	Malvaceae	*Pavonia urens*	Herb			Cav.	2021
483	Malvaceae	*Sida acuta*	Herb			Burm.f.	1960s-1990s
484	Malvaceae	*Sida ovata*	Herb			Forssk.	1960s-1990s
485	Malvaceae	*Sida rhombifolia var. serratifolia*	Herb			(R. Wilczek & Steyaert) Verdc.	1960s-1990s
486	Malvaceae	*Sida spinosa*	Herb			L.	1960s-1990s
487	Malvaceae	*Urena lobata*	Herb			L.	1960s-1990s
488	Malvoideae	*Sida cordifolia*	Herb			L.	2021
489	Melastomataceae	*Heterotis rotundifolia*	Herb			(Sm.) Jacq.-Fél.	2021
490	Meliaceae	*Azadirachta indica*	Tree			A. Juss.	2021
491	Meliaceae	*Khaya anthotheca*	Tree	VU		(Welw.) C. DC.	2021
492	Meliaceae	*Lepidotrichilia volkensii*	Tree			(Gürke) Leroy	2021
493	Meliaceae	*Trichilia emetica*	Tree			Vahl	1960s-1990s
494	Meliaceae	*Turraea holstii*	Tree			Gürke	2021
495	Meliaceae	*Turraea mombassana*	Tree			DC	1960s-1990s
496	Melianthaceae	*Bersama abyssinica*	Tree			Fres	1960s-1990s
497	Menispermacea	*Cissampelos pareira*	Herb			L	1960s-1990s
498	Menispermacea	*Stephania abyssinica*	Tree			Dillon & A.Rich	1960s-1990s
499	Mimosaceae	*Vachellia robusta*	Tree			(Burch.) Kyal. & Boatwr.	1960s-1990s
500	Mimosoideae	*Albizia amara*	Tree			(Roxb.) Boivin	2021
501	Mimosoideae	*Albizia anthelmintica*	Tree			Brongn.	1960s-1990s
502	Mimosoideae	*Albizia gummifera*	Tree			(J.F Gmel) A.R.Sm	1960s-1990s
503	Mimosoideae	*Albizia harveyi*	Tree			Fourn	1960s-1990s
504	Mimosoideae	*Albizia lebbeck*	Tree			(L.) Benth	1960s-1990s
505	Mimosoideae	*Albizia versicolor*	Tree			Welw. Ex. Oliv	1960s-1990s
506	Mimosoideae	*Dichrostachys cinerea*	Tree			(L.) Wight & Arn.	2021

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507	Mimosoideae	*Entada rheedei subsp. rheedei*	liana			DC.	1960s-1990s
508	Mimosoideae	*Mimosa pigra*	Tree			L.	1960s-1990s
509	Mimosoideae	*Newtonia buchananii*	Tree			(Bak) Gilg.	1960s-1990s
510	Mimosoideae	*Parkia filicoidea*	Tree			Welw. ex Oliv.	2021
511	Mimosoideae	*Senegalia brevispica*	Tree			(Harms) Seigler & Ebinger	1960s-1990s
512	Mimosoideae	*Senegalia mellifera*	Tree			(Vahl) Seigler & Ebinger	1960s-1990s
513	Mimosoideae	*Senegalia nigrescens*	Tree			(Oliv.) P.J.H.Hurter	1960s-1990s
514	Mimosoideae	*Senegalia polyacantha*	Tree			(Willd.) Seigler & Ebinger	2021
515	Mimosoideae	*Senegalia senegal*	Tree			(L.) Britton	1960s-1990s
516	Mimosoideae	*Vachellia abyssinica*	Tree			(Hochst. ex Benth.) Kyal. & Boatwr.	2021
517	Mimosoideae	*Vachellia drepanolobium*	Tree			(Harms ex Y.Sjöstedt) P.J.H.Hurter	1960s-1990s
518	Mimosoideae	*Vachellia hockii*	Tree			(De Wild.) Seigler & Ebinger	1960s-1990s
519	Mimosoideae	*Vachellia nilotica*	Tree			(L.) P.J.H.Hurter & Mabb.	1960s-1990s
520	Mimosoideae	*Vachellia sieberiana*	Tree			(DC.) Kyal. & Boatwr.	1960s-1990s
521	Mimosoideae	*Vachellia stuhlmannii*	Tree			(Taub.) Kyal. & Boatwr.	1960s-1990s
522	Mimosoideae	*Xylia Africana*	Tree	EN	Tanzania	Harms	2021
523	Mimosoideae	*Vachellia xanthophloea*	Tree			(Benth.) Banfi & Galasso	1960s-1990s
524	Montiniaceae	*Grevea eggelingii*	Tree			Milne - Redhead	1960s-1990s
525	Moraceae	*Antiaris toxicaria*	Tree			(Pers.) Lesch.	2021
526	Moraceae	*Ficus cordata*	Tree			Thunb.	2021
527	Moraceae	*Ficus craterostoma*	Tree			Warb. ex Mildbr. & Burret	2021
528	Moraceae	*Ficus mucuso*	Tree			Ficalho	1960s-1990s
529	Moraceae	*Ficus platyphylla*	Tree			Del	1960s-1990s
530	Moraceae	*Ficus sansibarica*	Tree			Warb.	1960s-1990s
531	Moraceae	*Ficus sur*	Tree			Forssk.	1960s-1990s
532	Moraceae	*Ficus sycomorus*	Tree			L.	2021
533	Moraceae	*Milicia excelsa*	Tree	NT		(Welw.) G,C. Berg	1960s-1990s
534	Moraceae	*Myrianthus holstii*	Tree			Engl	1960s-1990s
535	Musaceae	*Ensete ventricosum*	Herb			(Welw.) Cheesman	2021
536	Myrtaceae	*Syzygium cordatum*	Tree			Hochst.	1960s-1990s
537	Myrtaceae	*Syzygium cumini*	Tree			(L.) Skeels	2021
538	Myrtaceae	*Syzygium guineense*	Tree			(Willd.) DC	1960s-1990s
539	Nyctaginaceae	*Boerhavia coccinea*	Herb			Mill	1960s-1990s
540	Nyctaginaceae	*Boerhavia diffusa*	Herb			L.	1960s-1990s
541	Nymphaeaceae	*Nymphaea lotus*	Herb			L	1960s-1990s

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542	Ochnaceae	*Ochna atropurpurea*	Tree			DC.	2021
543	Ochnaceae	*Ochna holstii*	Tree			Engl	1960s-1990s
544	Ochnaceae	*Ochna macrocalyx*	Tree			Oliv.	2021
545	Ochnaceae	*Ochna schweinfurthiana*	Tree			F.Hoffin	1960s-1990s
546	Olacaceae	*Strombosia scheffleri*	Tree			Engl	1960s-1990s
547	Oleaceae	*Jasminum fluminense*	Tree			Vell	1960s-1990s
548	Oleaceae	*Noronhia mildbraedii*	Climber			(Gilg & G.Schellenb.) Hong-Wa & Besnard	1960s-1990s
549	Oleaceae	*Schrebera trichoclada*	Shrub			Welw.	1960s-1990s
550	Onagraceae	*Ludwigia adscendens subsp. diffusa*	Herb			(Forssk.) P. H. Raven	1960s-1990s
551	Onagraceae	*Ludwigia jussiaeoides*	Herb			Desr.	1960s-1990s
552	Onagraceae	*Ludwigia perennis*	Herb			L.	1960s-1990s
553	Orchidaceae	*Bulbophyllum intertextum*	Herb			Lindl.	2021
554	Orchidaceae	*Eulophia speciosa*	Herb			(R.Br.) Bolus	1960s-1990s
555	Oxalidaceae	*Biophytum umbraculum*	Herb			Welw.	1960s-1990s
556	Orchidaceae	*Polystachya isochiloides*	Herb	EN		Summerh.	1960s-1990s
557	Oxalidaceae	*Oxalis corniculata*	Herb			L.	1960s-1990s
558	Palmae	*Borassus aethiopum*	Herb			Mart.	1960s-1990s
559	Palmae	*Hyphaene petersiana*	Herb			Klotzsch ex Mart.	1960s-1990s
560	Palmae	*Phoenix reclinata*	Herb			Jacq.	1960s-1990s
561	Palmae	*Urochloa trichopus*	Herb			(Hochst.) Stapf	1960s-1990s
562	Fabaceae	*Abrus fruticulosus*	Herb			Wall. ex Wight & Arn.	1960s-1990s
563	Fabaceae	*Adenodolichos punctatus*	Herb			(Micheli) Harms	1960s-1990s
564	Fabaceae	*Aeschynomene indica*	Herb			L.	1960s-1990s
565	Fabaceae	*Aganope stuhlmannii*	Herb			(Taub.) Adema	1960s-1990s
566	Fabaceae	*Alysicarpus glumaceus*	Herb			(Vahl) DC.	1960s-1990s
567	Fabaceae	*Aeschynomene mossoensis*	Herb			J.Léonard	1960s-1990s
568	Fabaceae	*Alysicarpus rugosus*	Herb			J. Leon	1960s-1990s
569	Fabaceae	*Clitoria ternatea*	Herb			L.	1960s-1990s
570	Fabaceae	*Crotalaria agatiflora*	Herb			Schweinf.	1960s-1990s
571	Fabaceae	*Crotalaria barkae*	Herb			Schweinf.	1960s-1990s
572	Fabaceae	*Crotalaria bernieri*	Herb			Baill.	1960s-1990s
573	Fabaceae	*Crotalaria brevidens*	Herb			Benth (Kl)	1960s-1990s
574	Fabaceae	*Crotalaria calycina*	Herb			Schrank	1960s-1990s
575	Fabaceae	*Crotalaria cephalotes*	Herb			Steud. ex A.Rich.	1960s-1990s
576	Fabaceae	*Crotalaria goodiiformis*	Herb			Vatke	1960s-1990s
577	Fabaceae	*Crotalaria laburnifolia*	Herb			L.	1960s-1990s
578	Fabaceae	*Crotalaria lanceolata*	Herb			E. Mey	1960s-1990s
579	Fabaceae	*Crotalaria pterocalyx*	Herb			Harms	1960s-1990s
580	Fabaceae	*Crotalaria spinosa*	Herb			Benth	1960s-1990s
581	Fabaceae	*Crotalaria vasculosa*	Herb			Wall. ex Benth.	1960s-1990s

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582	Fabaceae	*Dalbergia armata*	Herb			E.Mey.	2021
583	Fabaceae	*Dalbergia boehmii*	Herb			Taub.	1960s-1990s
584	Fabaceae	*Dalbergia lactea*	Herb			Vatke	1960s-1990s
585	Fabaceae	*Dalbergia nitidula*	Herb			Welw. ex Baker	2021
586	Fabaceae	*Desmodium tortuosum*	Herb			(Sw.) DC.	1960s-1990s
587	Fabaceae	*Dolichos trilobus*	Herb			L.	1960s-1990s
588	Fabaceae	*Dalbergia melanoxylon*	Herb	NT		Guill & Perr	1960s-1990s
589	Fabaceae	*Grona barbata*	Herb			(L.) H.Ohashi & K.Ohashi	1960s-1990s
590	Fabaceae	*Hylodesmum repandum*	Herb			(Vahl) H.Ohashi & R.R.Mill	2021
591	Fabaceae	*Indigofera colutea*	Herb			(Burm.f.) Merr.	1960s-1990s
592	Fabaceae	*Indigofera demissa*	Herb			Taub.	1960s-1990s
593	Fabaceae	*Indigofera dendroides*	Herb			Jacq.	1960s-1990s
594	Fabaceae	*Indigofera drepanocarpa*	Herb			Taub.	1960s-1990s
595	Fabaceae	*Indigofera dyeri*	Herb			Britten	1960s-1990s
596	Fabaceae	*Indigofera hirsuta*	Herb			L.	1960s-1990s
597	Fabaceae	*Indigofera rhynchocarpa*	Herb			Welw. ex Baker	2021
598	Fabaceae	*Indigofera secundiflora*	Herb			Poir.	1960s-1990s
599	Fabaceae	*Indigofera sisalis*	Herb			J.B.Gillett	1960s-1990s
600	Fabaceae	*Indigofera spicata*	Herb			Forssk.	1960s-1990s
601	Fabaceae	*Lonchocarpus capassa*	Herb			Rolfe	1960s-1990s
602	Fabaceae	*Macrotyloma axillare*	Herb			(E.Mey.) Verdc.	1960s-1990s
603	Fabaceae	*Millettia usaramensis*	Herb			Taub.	1960s-1990s
604	Fabaceae	*Mucuna pruriens*	Herb			(L.) DC.	1960s-1990s
605	Fabaceae	*Neorautanenia mitis*	Herb			(A.Rich.) Verdc.	1960s-1990s
606	Fabaceae	*Ormocarpum trichocarpum*	Herb			(Taub.) Engl.	2021
607	Fabaceae	*Pericopsis angolensis*	Herb			(Bak) Van Meenwen	1960s-1990s
608	Fabaceae	*Philenoptera bussei*	Herb			(Harms) Schrire	1960s-1990s
609	Fabaceae	*Philenoptera eriocalyx*	Herb			(Harms) Schrire	2021
610	Fabaceae	*Pleurolobus gangeticus*	Herb			(L.) J.St.-Hil. ex H.Ohashi & K.Ohashi	1960s-1990s
611	Fabaceae	*Pseudarthria hookeri*	Herb			Wight & Arn.	2021
612	Fabaceae	*Psophocarpus scandens*	Herb			(Endl.) Verdc.	1960s-1990s
613	Fabaceae	*Pterocarpus angolensis*	Herb			DC.	1960s-1990s
614	Fabaceae	*Pterocarpus rotundifolius*	Herb			(Sond.) Druce	1960s-1990s
615	Fabaceae	*Pterocarpus tinctorius*	Herb			Welw.	2021
616	Fabaceae	*Rhynchosia albissima*	Herb			Gand.	1960s-1990s
617	Fabaceae	*Rhynchosia micrantha*	Herb			Harms	1960s-1990s
618	Fabaceae	*Rhynchosia minima*	Herb			(L.) DC.	1960s-1990s
619	Fabaceae	*Rhynchosia resinosa*	Herb			(Hochst. ex A.Rich.) Baker	1960s-1990s
620	Fabaceae	*Rhynchosia sublobata*	Herb			(Schumach.) Meikle	1960s-1990s

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621	Fabaceae	*Rhynchosia usambarensis*	Herb			Taub.	1960s-1990s
622	Fabaceae	*Rhynchosia villosa*	Herb			(Meisn.) Druce	2021
623	Fabaceae	*Rhynchosia viscosa*	Herb			DC.	1960s-1990s
624	Fabaceae	*Sesbania greenwayi*	Herb			Gillet	1960s-1990s
625	Fabaceae	*Tephrosia pumila*	Herb			(Lam.) Pers.	1960s-1990s
626	Fabaceae	*Tephrosia purpurea*	Herb			(L.) Pers.	1960s-1990s
627	Fabaceae	*Tephrosia stormsii*	Herb			De Willd.	1960s-1990s
628	Fabaceae	*Tephrosia uniflora*	Herb			Pers.	1960s-1990s
629	Fabaceae	*Tephrosia villosa*	Herb			(L.) Pers.	1960s-1990s
630	Fabaceae	*Teramnus labialis*	Herb			(L.f.) Spreng.	1960s-1990s
631	Fabaceae	*Teramnus uncinatus*	Herb			(L.) Sweet.	1960s-1990s
632	Fabaceae	*Trichocladus crinitus*	Herb			(Thunb.) Pers.	2021
633	Fabaceae	*Uraria picta*	Herb			(Jacq.) Desv. ex DC.	1960s-1990s
634	Fabaceae	*Vigna friesiorum*	Herb			Harms	1960s-1990s
635	Fabaceae	*Vigna unguiculata subsp. pubescens*	Herb			(R.Wilczek) Pasquet	1960s-1990s
636	Fabaceae	*Vigna vexillata*	Herb			(L.) A.Rich.	1960s-1990s
637	Fabaceae	*Zornia glochidiata*	Herb			Rchb. ex DC.	1960s-1990s
638	Passifloraceae	*Basananthe hanningtoniana*	Herb			(Mast.) J. J. de Wilde	1960s-1990s
639	Passifloraceae	*Schlechterina mitostemmatoides*	Shrub			Harms	1960s-1990s
640	Pedaliaceae	*Sesamum angolense*	Herb			Welw.	1960s-1990s
641	Pedaliaceae	*Sesamum angustifolium*	Herb			(Oliv.) Engl.	1960s-1990s
642	Phyllanthaceae	*Phyllanthus reticulatus*	Tree			Poir.	2021
643	Piperaceae	*Piper capense*	Shrub			L. fil.	1960s-1990s
644	Piperaceae	*Piper umbellatum*	Shrub			L.	1960s-1990s
645	Plumbaginaceae	*Plumbago zeylanica*	Shrub			L.	1960s-1990s
646	Poaceae	*Andropogon gayanus*	Grass			Kunth.	1960s-1990s
647	Poaceae	*Andropogon schirensis*	Grass			Hochst. ex A.Rich.	1960s-1990s
648	Poaceae	*Aristida adscensionis*	Grass			L.	1960s-1990s
649	Poaceae	*Aristida hordeacea*	Grass			Kunth.	1960s-1990s
650	Poaceae	*Bothriochloa bladhii*	Grass			(Retz.) S.T.Blake	1960s-1990s
651	Poaceae	*Bothriochloa insculpta*	Grass			(Hochst. ex A.Rich.) A.Camus	1960s-1990s
652	Poaceae	*Bothriochloa radicans*	Grass			(Lehm.) A.Camus	1960s-1990s
653	Poaceae	*Cenchrus purpureus*	Grass			(Schumach.) Morrone	2021
654	Poaceae	*Cenchrus ramosus*	Grass			(Hochst.) Morrone	1960s-1990s
655	Poaceae	*Cenchrus unisetus*	Grass			(Nees) Morrone	1960s-1990s
656	Poaceae	*Chloris gayana*	Grass			Kunth.	1960s-1990s
657	Poaceae	*Chloris pycnothrix*	Grass			Trin.	1960s-1990s
658	Poaceae	*Chloris virgata*	Grass			Sw.	1960s-1990s
659	Poaceae	*Cleistachne sorghoides*	Grass			Benth.	1960s-1990s
660	Poaceae	*Cymbopogon giganteus*	Grass			Chiov.	1960s-1990s

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661	Poaceae	*Cynodon dactylon*	Grass			(L.) Pers.	2021
662	Poaceae	*Cynodon nlemfuensis*	Grass			Vanderyst	1960s-1990s
663	Poaceae	*Dactyloctenium aegyptium*	Grass			(L.) Willd.	1960s-1990s
664	Poaceae	*Dactyloctenium giganteum*	Grass			B.S.Fisher & Schweick.	1960s-1990s
665	Poaceae	*Dichanthium annulatum*	Grass			(Forssk.) Stapf	1960s-1990s
666	Poaceae	*Dichanthium aristatum*	Grass			(Poir) C.E. Hubbard	1960s-1990s
667	Poaceae	*Diectomis fastigiata*	Grass			(Sw.) P.Beauv.	1960s-1990s
668	Poaceae	*Digitaria ciliaris*	Grass			(Retz) Koel	1960s-1990s
669	Poaceae	*Digitaria horizontalis*	Grass			Willd	1960s-1990s
670	Poaceae	*Digitaria milanjiana*	Grass			(Rendle) Stapf	1960s-1990s
671	Poaceae	*Digitaria ternata*	Grass			(A.Rich.) Stapf	1960s-1990s
672	Poaceae	*Digitaria velutina*	Grass			(Forssk.) R. Beauv.	1960s-1990s
673	Poaceae	*Diheteropogon amplectens*	Grass			(Nees) W.D. Clayton .var	1960s-1990s
674	Poaceae	*Disakisperma obtusiflorum*	Grass			(Hochst.) P.M.Peterson & N.Snow	1960s-1990s
675	Poaceae	*Echinochloa haploclada*	Grass			(Stapf) Stapf	1960s-1990s
676	Poaceae	*Echinochloa stagnina*	Grass			(Retz.) P.Beauv.	1960s-1990s
677	Poaceae	*Echinochloa ugandensis*	Grass			Snowden	1960s-1990s
678	Poaceae	*Eleusine africana*	Grass			Kennedy - O' Bryne	1960s-1990s
679	Poaceae	*Eleusine coracana*	Grass			Gaertn	1960s-1990s
680	Poaceae	*Eleusine indica*	Grass			(L.) Gaertn.	1960s-1990s
681	Poaceae	*Elymandra grallata*	Grass			(Stapf) W.D. Clayton	1960s-1990s
682	Poaceae	*Enteropogon macrostachyus*	Grass			(A.Rich.) Benth.	1960s-1990s
683	Poaceae	*Enteropogon sechellensis*	Grass			(Baker) Th.Dur. & Schinz	1960s-1990s
684	Poaceae	*Eragrostis aethiopica*	Grass			Chiov.	1960s-1990s
685	Poaceae	*Eragrostis aspera*	Grass			(Jacq.) Nees	1960s-1990s
686	Poaceae	*Eragrostis cilianensis*	Grass			(All.) Vignolo ex Janch.	1960s-1990s
687	Poaceae	*Eragrostis ciliaris*	Grass			(L.) R. Br.	1960s-1990s
688	Poaceae	*Eragrostis cylindriflora*	Grass			Hochst.	1960s-1990s
689	Poaceae	*Eragrostis lappula*	Grass			Nees	1960s-1990s
690	Poaceae	*Eragrostis minor*	Grass			Hochst.	1960s-1990s
691	Poaceae	*Eragrostis pilosa*	Grass			(L.) P. Beauv.	1960s-1990s
692	Poaceae	*Eragrostis superba*	Grass			Peyr.	1960s-1990s
693	Poaceae	*Eragrostis tenella*	Grass			(L.) Roem. & Schult.	1960s-1990s
694	Poaceae	*Eragrostis tenuifolia*	Grass			(A.Rich) Steud	1960s-1990s
695	Poaceae	*Eriochloa barbatus*	Grass			(Trin.) S.Yadav & M.R.Almeida	1960s-1990s
696	Poaceae	*Eriochloa meyeriana*	Grass			(Nees) Pilg.	1960s-1990s

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697	Poaceae	*Euclasta condylotricha*	Grass			(Hochst. ex Steud.) Stapf	1960s-1990s
698	Poaceae	*Hackelochloa granularis*	Grass			(L.) Kuntze	1960s-1990s
699	Poaceae	*Heteropogon contortus*	Grass			(L.) Roem. & Schult.	1960s-1990s
700	Poaceae	*Hyparrhenia collina*	Grass			(Pilg.) Stapf	2021
701	Poaceae	*Hyparrhenia cymbaria*	Grass			(L.) Stapf	2021
702	Poaceae	*Hyparrhenia filipendula*	Grass			(Hochst.) Stapf	1960s-1990s
703	Poaceae	*Hyparrhenia finitima*	Grass			(Hotchst.) Stapf	1960s-1990s
704	Poaceae	*Hyparrhenia nyassae*	Grass			(Rendle) Stapf	2021
705	Poaceae	*Hyparrhenia rufa*	Grass			(Hotchst.) Stapf	1960s-1990s
706	Poaceae	*Hyperthelia dissoluta*	Grass			(Steud.) W.D.Clayton	1960s-1990s
707	Poaceae	*Leersia hexandra*	Grass			Sw.	1960s-1990s
708	Poaceae	*Leptaspis zeylanica*	Grass			Nees ex Steud.	2021
709	Poaceae	*Leptochloa panicea*	Grass			(Retz.) Ohwi	1960s-1990s
710	Poaceae	*Loudetia simplex*	Grass			(Nees) C.E.Hubbard	1960s-1990s
711	Poaceae	*Megathyrsus infestus*	Grass			(Andersson) B.K.Simon & S.W.L.Jacobs	1960s-1990s
712	Poaceae	*Megathyrsus maximus*	Grass			(Jacq.) B.K.Simon & S.W.L.Jacobs	1960s-1990s
713	Poaceae	*Melinis repens*	Grass			(Willd.) Zizka	1960s-1990s
714	Poaceae	*Moorochloa eruciformis*	Grass			(Sm.) Veldkamp	1960s-1990s
715	Poaceae	*Olyra latifolia*	Grass			L.	2021
716	Poaceae	*Oplismenus compositus*	Grass			(L) Beauv	1960s-1990s
717	Poaceae	*Oplismenus hirtellus*	Grass			(L.) P. Beauv.	1960s-1990s
718	Poaceae	*Oryza eichingeri*	Grass			Peter	1960s-1990s
719	Poaceae	*Oryza punctata*	Grass			Steud.	1960s-1990s
720	Poaceae	*Panicum atrosanguineum*	Grass			A.Rich.	1960s-1990s
721	Poaceae	*Panicum coloratum*	Grass			L.	1960s-1990s
722	Poaceae	*Panicum comorense*	Grass			Mez.	1960s-1990s
723	Poaceae	*Panicum deustum*	Grass			Thunb	1960s-1990s
724	Poaceae	*Panicum laticomum*	Grass			Nees	1960s-1990s
725	Poaceae	*Panicum massaiense*	Grass			Stapf	1960s-1990s
726	Poaceae	*Panicum pansum*	Grass			Rendle	1960s-1990s
727	Poaceae	*Panicum poioides*	Grass			Stapf	1960s-1990s
728	Poaceae	*Panicum porphyrrhizos*	Grass			Steud.	1960s-1990s
729	Poaceae	*Panicum trichocladum*	Grass			Hack. ex K.Schum.	1960s-1990s
730	Poaceae	*Paspalum scrobiculatum*	Grass			L.	1960s-1990s
731	Poaceae	*Perotis patens*	Grass			Gand	1960s-1990s
732	Poaceae	*Phragmites mauritianus*	Grass			Kunth.	1960s-1990s
733	Poaceae	*Phyllorachis sagittata*	Grass			Trimen	1960s-1990s
734	Poaceae	*Rhynchelytrum repens*	Grass			(Willd.) C.E.Hubb.	1960s-1990s
735	Poaceae	*Rottboellia cochinchinensis*	Grass			(Lour.) Clayton	1960s-1990s

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736	Poaceae	*Sacciolepis africana*	Grass			C.E.Hubbard	1960s-1990s
737	Poaceae	*Sacciolepis myosuroides*	Grass			(R.Br.) Chase ex E.G.Camus & A.Camus	1960s-1990s
738	Poaceae	*Sarga versicolor*	Grass			(Andersson) Spangler	1960s-1990s
739	Poaceae	*Schizachyrium brevifolium*	Grass			(Sw.) Nees.	1960s-1990s
740	Poaceae	*Setaria homonyma*	Grass			(Steud) Chiov.	1960s-1990s
741	Poaceae	*Setaria incrassata*	Grass			(Hochst.) Hack.	1960s-1990s
742	Poaceae	*Setaria longiseta*	Grass			P.Beauv	1960s-1990s
743	Poaceae	*Setaria megaphylla*	Grass			(Steud.) T.Durand & Schinz	2021
744	Poaceae	*Setaria pallide*	Grass			fusca (K.Schum) Stapf & Hubbard	1960s-1990s
745	Poaceae	*Setaria parviflora*	Grass			(Poir.) Kerguélen	1960s-1990s
746	Poaceae	*Setaria pumila*	Grass			(Poir) Roem and Schult.	1960s-1990s
747	Poaceae	*Setaria sagittifolia*	Grass			(A.Rich.) Walp.	1960s-1990s
748	Poaceae	*Setaria sphacelata*	Grass			(K.Schum.) Moss	1960s-1990s
749	Poaceae	*Setaria verticillata*	Grass			(L.) P.Beauv.	1960s-1990s
750	Poaceae	*Sorghastrum incompletum var. africanum*	Grass			(Franch.) ined.	1960s-1990s
751	Poaceae	*Sorghastrum stipoides*	Grass			(Kunth) Nash	1960s-1990s
752	Poaceae	*Sorghum arundinaceum*	Grass			(Desv.) Stapf.	1960s-1990s
753	Poaceae	*Sporobolus festivus*	Grass			Hochst.	1960s-1990s
754	Poaceae	*Sporobolus fimbriatus*	Grass			Nees	1960s-1990s
755	Poaceae	*Sporobolus helvolus*	Grass			(Trin) Durand	1960s-1990s
756	Poaceae	*Sporobolus ioclados*	Grass			(Trin) Nees	1960s-1990s
757	Poaceae	*Sporobolus pyramidalis*	Grass			Beauv	1960s-1990s
758	Poaceae	*Sporobolus tenuissimus*	Grass			(K.Schum) Kuntze	1960s-1990s
759	Poaceae	*Thelepogon elegans*	Grass			Roth	1960s-1990s
760	Poaceae	*Themeda triandra*	Grass			Forssk	1960s-1990s
761	Poaceae	*Tragus berteronianus*	Grass			Schult	1960s-1990s
762	Poaceae	*Tragus heptaneuron*	Grass			W.D.Clayton	1960s-1990s
763	Poaceae	*Trigonochloa uniflora*	Grass			(Hochst. ex A.Rich.) P.M.Peterson & N.Snow	1960s-1990s
764	Poaceae	*Urochloa brizantha*	Grass			(A.Rich.) R.D.Webster	1960s-1990s
765	Poaceae	*Urochloa deflexa*	Grass			(Schumach.) H.Scholz	1960s-1990s
766	Poaceae	*Urochloa reptans*	Grass			(L.) Stapf	1960s-1990s
767	Poaceae	*Urochloa xantholeu-ca var. xantholeuca*	Grass			Stapf	1960s-1990s
768	Polygalaceae	*Polygala albida*	Herb			Schinz	1960s-1990s
769	Polygalaceae	*Polygala erioptera*	Herb			DC	1960s-1990s
770	Polygalaceae	*Polygala kilimandjarica*	Herb			Chodat	1960s-1990s

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771	Polygalaceae	*Polygala macrostigma*	Herb			Chodat	1960s-1990s
772	Polygalaceae	*Polygala sphenoptera*	Herb			Fresen.	1960s-1990s
773	Polygonaceae	*Oxygonum sinuatum*	Herb			(Hochst. & Steud. ex Meisn.) Damm.	1960s-1990s
774	Polygonaceae	*Persicaria amphibia*	Herb			(L.) Gray	1960s-1990s
775	Portulacaceae	*Portulaca oleracea*	Herb			L.	1960s-1990s
776	Portulacaceae	*Portulaca quadrifida*	Herb			L.	1960s-1990s
777	Portulacaceae	*Talinum caffrum*	Herb			(Thunb.) Eckl. & Zeyh.	1960s-1990s
778	Portulacaceae	*Talinum portulacifolium*	Herb			(Forssk.) Shweinf	1960s-1990s
779	Proteaceae	*Faurea rochetiana*	Herb			(A. Rich.) Chiov. ex Pic. Serm.	2021
780	Pteridaceae	*Pteris catoptera*	Herb			Kunze	2021
781	Putranjivaceae	*Drypetes natalensis*	Tree			(Harv.) Hutch.	2021
782	Rhamnaceae	*Berchemia discolor*	Tree			(Klotzsch) Hemsl.	1960s-1990s
783	Rhamnaceae	*Helinus integrifolius*	Tree			(Lam) Kuntze	1960s-1990s
784	Rhamnaceae	*Lasiodiscus usambarensis*	Tree			Engl.	2021
785	Rhamnaceae	*Ziziphus mucronata*	Tree			Willd	1960s-1990s
786	Rhamnaceae	*Ziziphus pubescens*	Tree			Oliv	1960s-1990s
787	Rubiaceae	*Afrocanthium burttii*	Tree			(Bullock) Lantz	2021
788	Rubiaceae	*Aidia micrantha*	Tree			(K.Schum.) Bullock ex F.White	2021
789	Rubiaceae	*Breonadia salicina*	Tree			(Vahl) H. & Wood	1960s-1990s
790	Rubiaceae	*Bullockia setiflora*	Tree			(Hiern) Razafim., Lantz & B.Bremer	1960s-1990s
791	Rubiaceae	*Catunaregam nilotica*	Tree			(Stapf) Tirveng.	1960s-1990s
792	Rubiaceae	*Catunaregam spinosa*	Tree			(Thunb.) Tirveng.	2021
793	Rubiaceae	*Chassalia discolor*	Tree			K.Schum	1960s-1990s
794	Rubiaceae	*Coffea mufindiensis*	Tree			Hutch. ex Bridson	2021
795	Rubiaceae	*Cordylostigma longifolium*	Tree			(Klotzsch) Groeninckx & Dessein	1960s-1990s
796	Rubiaceae	*Cordylostigma obtusilobum*	Tree			(Hiern) Groeninckx & Dessein	1960s-1990s
797	Rubiaceae	*Cordylostigma virgatum*	Tree			(Willd.) Groeninckx & Dessein	1960s-1990s
798	Rubiaceae	*Coffea bridsoniae*	Tree	EN	Tanzania	A.P.Davis & Mvungi	2021
799	Rubiaceae	*Cremaspora triflora*	Tree			(Thonn.) K.Schum.	2021
800	Rubiaceae	*Coffea kihansiensis*	Tree	CR	Tanzania	A.P.Davis & Mvungi	2021
801	Rubiaceae	*Crossopteryx febrifuga*	Tree			(Afzel. ex G.Don) Benth.	1960s-1990s
802	Rubiaceae	*Gardenia volkensii*	Tree			K.Schum.	2021
803	Rubiaceae	*Coffea pseudozanguebariae*	Tree	NT	Kenya and Tanzania	Bridson	2021

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804	Rubiaceae	*Heinsia crinita*	Tree			(Wennberg) G.Taylor	1960s-1990s
805	Rubiaceae	*Keetia gueinzii*	Tree			(Sond) Bridson	1960s-1990s
806	Rubiaceae	*Keetia venosa*	Tree			(Oliv) Bridson	1960s-1990s
807	Rubiaceae	*Keetia zanzibarica*	Tree			(KI) Bridson	1960s-1990s
808	Rubiaceae	*Leptactina platyphylla*	Tree			(Hiern) Wernham	1960s-1990s
809	Rubiaceae	*Meyna tetraphylla*	Tree			(Schweinf. ex Hiern) Robyns	1960s-1990s
810	Rubiaceae	*Didymosalpinx norae*	Tree	NT		(Swynn.) Keay	2021
811	Rubiaceae	*Oldenlandia affinis*	Tree			(Roem & Schult) DC	1960s-1990s
812	Rubiaceae	*Empogona ovalifolia*	Tree			(Hiern) Tosh & Robbr.	2021
813	Rubiaceae	*Oldenlandia corymbosa*	Tree			L.	1960s-1990s
814	Rubiaceae	*Oldenlandia fastigiata*	Tree			Bremek	1960s-1990s
815	Rubiaceae	*Oldenlandia herbacea*	Tree			(L) Roxb	1960s-1990s
816	Rubiaceae	*Oxyanthus pyriformis*	Tree			(Hochst) Skeels	1960s-1990s
817	Rubiaceae	*Pauridiantha paucinervis*	Tree			(Hiern)Bremek (K.Schum)	1960s-1990s
818	Rubiaceae	*Pavetta arbetina*	Tree				1960s-1990s
819	Rubiaceae	*Pavetta fascifolia*	Tree			Bremek.	1960s-1990s
820	Rubiaceae	*Pavetta oliveriana*	Tree			Hiern	1960s-1990s
821	Rubiaceae	*Mussaenda monticola*	Tree	VU		K. Krause	1960s-1990s
822	Rubiaceae	*Pavetta refractifolia*	Tree			K.Schum	1960s-1990s
823	Rubiaceae	*Pavetta schumanniana*	Tree			F.Hoffm. ex K.Schum.	1960s-1990s
824	Rubiaceae	*Pavetta subcana*	Tree			Hiern	1960s-1990s
825	Rubiaceae	*Phellocalyx vollesenii*	Tree			Bridson	1960s-1990s
826	Rubiaceae	*Polysphaeria dischistocalyx*	Tree			Brenan	1960s-1990s
827	Rubiaceae	*Polysphaeria lanceolata*	Tree			Hiern	1960s-1990s
828	Rubiaceae	*Polysphaeria lanceolata subsp. lanceolata*	Tree			Hiern	1960s-1990s
829	Rubiaceae	*Polysphaeria multiflora*	Tree			Hiern	2021
830	Rubiaceae	*Psychotria capensis*	Tree			(Eckl.) Vatke	2021
831	Rubiaceae	*Psychotria castaneifolia*	Tree			E.M.A.Petit	2021
832	Rubiaceae	*Psychotria lauracea*	Tree			(K.Schum.) E.M.A.Petit	1960s-1990s
833	Rubiaceae	*Psychotria mahonii*	Tree			C.H.Wright	2021
834	Rubiaceae	*Psychotria pumila*	Tree			Hiern	1960s-1990s
835	Rubiaceae	*Psychotria schliebenii*	Tree			E.M.A.Petit	2021
836	Rubiaceae	*Polysphaeria braunii*	Tree	VU	Tanzania	K. Krause	1960s-1990s
837	Rubiaceae	*Rhodopentas bussei*	Tree			(K.Krause) Kårehed & B.Bremer	1960s-1990s
838	Rubiaceae	*Rhodopentas parvifolia*	Tree			(Hiern) Kårehed & B.Bremer	1960s-1990s
839	Rubiaceae	*Rothmannia engleriana*	Tree			(K.Schum.) Keay	2021
840	Rubiaceae	*Rothmannia manganjae*	Tree			(Hiern) Keay	2021

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841	Rubiaceae	*Rytigynia celastroides*	Tree			(Baill.) Verdc.	1960s-1990s
842	Rubiaceae	*Rytigynia uhligii*	Tree			(K.Schum. & K.Krause) Verdc.	2021
843	Rubiaceae	*Spermacoce chaetocephala*	Tree			DC	1960s-1990s
844	Rubiaceae	*Spermacoce dibrachiata*	Tree			Oliv	1960s-1990s
845	Rubiaceae	*Spermacoce pusilla*	Tree			Wall	1960s-1990s
846	Rubiaceae	*Spermacoce sphaerostigma*	Tree			(A.Rich.) Oliv.	1960s-1990s
847	Rubiaceae	*Spermacoce subvulgata*	Tree			(K.Schum) Garcia	1960s-1990s
848	Rubiaceae	*Tarenna pavettoides*	Tree			(Harv.) Sim	2021
849	Rubiaceae	*Uncaria africana*	Tree			G.Don	2021
850	Rubiaceae	*Vangueria burnettii*	Tree			(Tennant) Lantz	1960s-1990s
851	Rubiaceae	*Vangueria infausta*	Tree			Burch	1960s-1990s
852	Rubiaceae	*Vangueria madagascariensis*	Tree			J.F.Gmel.	2021
853	Rutaceae	*Clausena anisata*	Tree			(Willd.) Hook. fil.	1960s-1990s
854	Rutaceae	*Vepris nobilis*	Tree			(Delile) Mziray	1960s-1990s
855	Rutaceae	*Vepris simplicifolia*	Tree			(I. Verd.) Mziray	1960s-1990s
856	Rutaceae	*Zanthoxylum asiaticum*	Tree			(L.) Appelhans, Groppo & J. Wen	1960s-1990s
857	Rutaceae	*Zanthoxylum chalybeum*	Tree			Engl	1960s-1990s
858	Salvadoraceae	*Salvadora persica*	Tree			L.	1960s-1990s
859	Sapindaceae	*Allophylus africanus*	Tree			P. Beauv.	2021
860	Sapindaceae	*Allophylus rubifolius*	Tree			(Hochst. ex A. Rich.) Engl.	1960s-1990s
861	Sapindaceae	*Allophylus rubifolius var. dasystachys*	Tree			(Gilg) Verdc.	1960s-1990s
862	Sapindaceae	*Deinbollia borbonica*	Tree			Scheff.	2021
863	Sapindaceae	*Deinbollia kilimandscharica*	Tree			Taub	1960s-1990s
864	Sapindaceae	*Haplocoelum inoploeum*	Tree			Radlk.	1960s-1990s
865	Sapindaceae	*Lecaniodiscus fraxinifolius*	Tree			Baker	2021
866	Sapindaceae	*Majidea zanguebarica*	Tree			J. Kirk	2021
867	Sapindaceae	*Pancovia golungensis*	Tree			(Hiern) Exell & Mendonça	2021
868	Sapindaceae	*Paullinia pinnata*	Tree			L.	2021
869	Sapotaceae	*Aningeria adolfi - friedericii*	Tree			(Engl) Robyns & Gilbert	1960s-1990s
870	Sapotaceae	*Gambeya gorungosana*	Tree			(Engl.) Liben	1960s-1990s
871	Sapotaceae	*Manilkara mochisia*	Tree			(Baill) Dubard	1960s-1990s
872	Sapotaceae	*Mimusops zeyheri*	Tree			Sond.	1960s-1990s
873	Sapotaceae	*Synsepalum cerasiferum*	Tree			(Welw.) T.D.Penn.	1960s-1990s
874	Scrophulariaceae	*Artanema longifolium*	Herb			(L.) Vatke	1960s-1990s
875	Scrophulariaceae	*Bacopa floribunda*	Herb			(R.Br) Wettst	1960s-1990s
876	Scrophulariaceae	*Buchnera hispida*	Herb			Buch.-Ham. ex D. Don	1960s-1990s
877	Scrophulariaceae	*Cycnium tubulosum*	Herb			(L. fil.) Engl.	1960s-1990s
878	Scrophulariaceae	*Cycnium tubulosum sub-sp. montanum*	Herb			(N. E. Br.) O. J. Hansen	1960s-1990s

SN	Family	Species name	Life-Form	IUCN status	Endemism	Author	Record status
879	Scrophulariaceae	*Striga asiatica*	Herb			L.Kuntze	1960s-1990s
880	Scrophulariaceae	*Striga gesnerioides*	Herb			(Willd.) Vatke	1960s-1990s
881	Simaroubaceae	*Brucea tenuifolia*	Shrub			Engl	1960s-1990s
882	Simaroubaceae	*Harrisonia abyssinica*	Shrub			Oliv	1960s-1990s
883	Sapotaceae	*Mimusops riparia*	Tree	VU	Kenya and Tanzania	Engl.	1960s-1990s
884	Simaroubaceae	*Odyendea zimmermannii*	Shrub			Engl	1960s-1990s
885	Smilacaceae	*Smilax anceps*	Shrub			Willd.	2021
886	Solanaceae	*Physalis peruviana*	Herb			L.	1960s-1990s
887	Solanaceae	*Solanum incanum*	Herb			L.	1960s-1990s
888	Solanaceae	*Solanum richardii*	Herb			Dunal	1960s-1990s
889	Solanaceae	*Withania somnifera*	Herb			(L) Dunal	1960s-1990s
890	Sphenocleaceae	*Sphenoclea zeylanica*	Herb			Gaertn	1960s-1990s
891	Sterculiaceae	*Dombeya acutangula sub-sp. acutangula*	Tree			*K. Schum. ex Engl.*	1960s-1990s
892	Sterculiaceae	*Dombeya burgessiae*	Tree			Gerrard ex Harv. & Sond.	2021
893	Sterculiaceae	*Dombeya rotundifolia*	Tree			(Hochst.) Planch.	2021
894	Sterculiaceae	*Dombeya shupangae*	Tree			K. Schum.	1960s-1990s
895	Sterculiaceae	*Leptonychia usambarensis*	Tree			K. Schum.	2021
896	Sterculiaceae	*Sterculia africana*	Tree			(Lour) Fiori	1960s-1990s
897	Sterculiaceae	*Sterculia appendiculata*	Tree			K. Schum. ex Engl.	1960s-1990s
898	Sterculiaceae	*Sterculia quinqueloba*	Tree			(Garcke) K. Schum	1960s-1990s
899	Sterculiaceae	*Waltheria indica*	Tree			L.	1960s-1990s
900	Thelypteridaceae	*Christella dentata*	Herb			(Forssk.) Brownsey & Jermy	1960s-1990s
901	Thymelaceae	*Dicranolepis usambarica*	Shrub			Gilg	1960s-1990s
902	Thymelaceae	*Peddiea fischeri*	Shrub			Engl.	2021
903	Thymelaceae	*Peddiea lanceolata*	Shrub			Domke	1960s-1990s
904	Thymelaeaceae	*Gnidia apiculata*	Herb			(Oliv.) Gilg	2021
905	Thymelaeaceae	*Synaptolepis kirkii*	Shrub			Oliv.	2021
906	Tiliaceae	*Corchorus aestuans*	Shrub			L.	1960s-1990s
907	Tiliaceae	*Corchorus fascicularis*	Shrub			Lam.	1960s-1990s
908	Tiliaceae	*Corchorus olitorius*	Shrub			L.	1960s-1990s
909	Tiliaceae	*Corchorus trilocularis*	Shrub			L.	1960s-1990s
910	Tiliaceae	*Grewia bicolor*	Shrub			Juss	1960s-1990s
911	Tiliaceae	*Grewia forbesii*	Shrub			Harv. ex Mast.	1960s-1990s
912	Tiliaceae	*Grewia lepidopetala*	Shrub			Garcke	1960s-1990s
913	Tiliaceae	*Grewia microcarpa*	Shrub			K. Schum	1960s-1990s
914	Tiliaceae	*Triumfetta annua*	Shrub			L.	1960s-1990s
915	Tiliaceae	*Triumfetta rhomboidea*	Shrub			Jacq	1960s-1990s
916	Turneraceae	*Tricliceras bivinianum*	Herb			(Tul.) R. Fern.	1960s-1990s
917	Turneraceae	*Tricliceras brevicaule*	Herb			(Urb.) R. Fern.	1960s-1990s
918	Turneraceae	*Tricliceras lobatum*	Shrub			(Urb.) R. Fern.	1960s-1990s
919	Turneraceae	*Tricliceras longipedunculta*	Herb			Mast.	1960s-1990s

SN	Family	Species name	Life-Form	IUCN status	Endemism	Author	Record status
920	Turneraceae	*Wormskioldia breuvicaulis*	Shrub			Urb	1960s-1990s
921	Ulmaceae	*Celtis gomphophylla*	Tree			Baker	2021
922	Umbelliferae	*Centella asiatica*	Herb			(L.) Urb	1960s-1990s
923	Umbelliferae	*Heteromorpha arborescens var. abyssinica*	Herb			(Hochst. ex A. Rich.) H. Wolff	1960s-1990s
924	Urticaceae	*Laportea interrupta*	Herb			(L) Chew	1960s-1990s
925	Urticaceae	*Laportea ovalifolia*	Herb			(Schum. & Thonn.) Chew	1960s-1990s
926	Verbenaceae	*Clerodendrum capitatum*	Herb			(Willd.) Schumach.	1960s-1990s
927	Verbenaceae	*Clerodendrum cephalanthum*	Herb			Oliv (Mildbr) Verde	1960s-1990s
928	Verbenaceae	*Clerodendrum pleiosciadium*	Herb			Gurke	1960s-1990s
929	Verbenaceae	*Clerodendrum ternatum*	Herb			Schinz	1960s-1990s
930	Verbenaceae	*Lantana camara*	Herb			L.	1960s-1990s
931	Verbenaceae	*Lantana trifolia*	Herb			L.	1960s-1990s
932	Verbenaceae	*Lantana ukambensis*	Herb			(Vatke) Verde	1960s-1990s
933	Verbenaceae	*Lippia javanica*	Herb			(Burm.f) Sprengel	1960s-1990s
934	Verbenaceae	*Premna hildebrandtii*	Herb			Gurke	1960s-1990s
935	Verbenaceae	*Rotheca myricoides*	Herb			(Hochst.) Steane & Mabb.	1960s-1990s
936	Verbenaceae	*Vitex doniana*	Herb			*Sweet*	1960s-1990s
937	Violaceae	*Pigea enneasperma*	Herb			(L.) P. I. Forst.	1960s-1990s
938	Violaceae	*Rinorea angustifolia*	Shrub			(Thouars) Baill.	1960s-1990s
939	Violaceae	*Rinorea elliptica*	Tree			(Oliv.) Kuntze	2021
940	Violaceae	*Rinorea ferruginea*	Tree			Engl	1960s-1990s
941	Violaceae	*Rinorea ilicifolia*	Tree			(Welw. ex Oliv.) Kuntze	1960s-1990s
942	Vitaceae	*Cissus cornifolia*	Shrub			(Baker) Planch.	1960s-1990s
943	Vitaceae	*Cissus phymatocarpa*	Herb			Masinde & L. E. Newton	1960s-1990s
944	Vitaceae	*Cissus rotundifolia*	Herb			(Forssk.) Vahl	1960s-1990s
945	Vitaceae	*Cyphostemma adenocaule*	Herb			(Steud. ex A. Rich.) Desc.	1960s-1990s
946	Vitaceae	*Cyphostemma gigantophyllum*	Herb			(Gilg & M. Brandt) Desc. ex Wild & R. B. Drumm.	1960s-1990s
947	Vitaceae	*Cyphostemma hildebrandtii*	Herb			(Gilg) Desc. ex Wild & R. B. Drumm.	1960s-1990s
948	Olacaceae	*Ximenia caffra*	Shrub			Sond.	2021
949	Zingiberaceae	*Aframomum angustifolium*	Herb			(Sonn.) K.Schum.	2021
950	Zingiberaceae	*Siphonochilus kirkii*	Herb			(Hook.f.) B.L.Burtt	1960s-1990s
951	Zygophyllaceae	*Tribulus terrestris*	Herb			L.	1960s-1990s

EVALUATING THE EFFECTIVENESS OF FORTIFIED LIVESTOCK ENCLOSURES AS A HUMAN-CARNIVORE CONFLICT MITIGATION TOOL IN TANZANIA'S RUAHA LANDSCAPE

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ABSTRACT:

Wildlife conflict with humans, particularly over livestock depredation, poses a severe and continuing threat to the conservation of large carnivores, reserve-adjacent and unprotected areas. Such conflict also inflicts substantial costs, including direct, indirect, and opportunity costs, on people living alongside large carnivores. Though conflict is complex, attacks upon livestock are one of the factors which drive immediate hostility towards carnivores, inflict economic damage upon livestock-keepers, and can lead to retaliatory and preventative carnivore killing. Many conflict mitigation and livestock protection approaches exist, but it is crucial to examine their effectiveness. In this study, we evaluated the effectiveness of fortified livestock enclosures in reducing livestock depredation in an area surrounding Ruaha National Park in southernhingland, Tanzania. These fortified enclosures are built with chain-link-fence and are aimed to replace the traditional enclosures built with acacia thorn branches. We implemented a before-after-control-impact (BACI) design to test the short-term impacts of the fortified enclosure intervention. We then conducted a cost-benefit analysis of the economic impact of livestock lost to carnivores and the cost of building the fortified enclosures (c. US$ 43-98). Finally, we tested the hypothesis that fortified enclosures would diminish in effectiveness over time as carnivores become habituated and thus depredation risk would increase. Across both short- and long-term analyses, fortified enclosures were effective at reducing the odds of experiencing livestock depredation by carnivores by 85% and 60%, respectively. Based on mean depredation rates (c. 0.10 livestock month^{-1}) and observed reductions, the average household would recoup the cost of basic fortified enclosure construction in 6 months with the current subsidy, or 2 years without subsidy. Our study contributes actionable evidence on the impact of an intervention to inform conservation strategies supporting human-carnivore coexistence.

Key words: Conflcits, Carnivore, Livestokc, fortified livestock enclosures

INTRODUCTION

Human-wildlife conflict is a serious and increasing threat to conservation, particularly for large carnivores (Nyhus P. 2016, Woodroffe *et al.* 2005), and also imposes substantial costs on human lives and livelihoods (Salerno *et al.* 2016; Thirgood, S., & Woodroffe, R. 2005). In regions where humans and wildlife, particularly dangerous megafauna, overlap, there is a need to develop and deploy effective strategies to reduce conflict and increase tolerance (Chapron, G. & Treves, A. 2016; Venumière-Lefebvre *et al.* 2022).

The conservation of African large carnivores exemplifies these coexistence challenges. Expanding human land use and associated anthropogenic pressures, including direct human-carnivore conflict, have led to the extirpation of African wild dog (*Lycaon pictus*), lion (*Panthera leo*) and cheetah (*Acinonyx jubatus*) from over 90% of their historic range (IUCN/SSC 2007, 2018). Lion populations are declining rapidly in all but a few remaining strongholds (Riggio *et al.* 2013; Bauer et al. 2015). With the potential exception of some fenced reserves, livestock depredation and associated conflict with livestock keepers will persist as a significant threat to both stronghold and fragmented carnivore populations (Macdonald & Sillero-Zubiri 2002; Bauer *et al.* 2016; Di Minin *et al.* 2021).

In places such as Tanzania, large carnivores still commonly range outside protected areas and frequently enter into conflict by killing livestock and people (Dickman *et al.* 2014, Lichtenfeld *et al.* 2015, Mwakatobe *et al.* 2013; Salerno *et al.* 2016). Large carnivores also impose substantial indirect and opportunity costs on people, for example when people are compelled to invest in livestock protection or limit activities because of fear of encountering predators (Dickman 2010). Retaliatory or preventive killings of carnivores are a common response to these pressures (e.g., Koziarski *et al.* 2016, Kissui 2008, Loveridge *et al.* 2010, Frank *et al.* 2005). For instance, among agropastoralist and pastoralist communities living in the Ruaha-Rungwa landscape, an important remaining stronghold for African lions (Riggio et al. 2013), large carnivores, especially lions, are viewed as widely problematic due to their predation upon culturally and economically valuable cattle (Dickman, 2010). While conflict reduction tools exist, practitioners often have limited evidence with which to evaluate their effectiveness over time (van Eeden *et al.* 2018; König *et al.* 2021).

Reducing livestock depredation and associated carnivore mortality in human-dominated landscapes is therefore understood as critical for coexistence (Dickman *et al.* 2014; Venumière-Lefebvre *et al.* 2022). Reducing livestock depredation generally can be associated with lower anthropogenic carnivore mortality (Ogada *et al.* 2003) and clear benefits livestock keepers. There are a variety of interventions being implemented globally that aim to reduce human-carnivore conflict, such as grazing strategies, livestock guarding dogs, carnivore hazing, and light and motion deterrents like fladry or strobes (van Eeden *et al.* 2018, Eklund *et al*. 2017, Miller *et al.* 2016).

Several studies have suggested that fortified livestock enclosures are a useful and cost-effective means to reduce livestock depredation by carnivores during the night

(Lichtenfeld *et al.* 2015, Stutton *et al.* 2019, Weise 2018, Lesilau *et al.* 2018, IUCN 2023), but analyses have so far been limited in their ability to make causal claims of impact. In this study, we evaluated the effectiveness of fortified livestock enclosures in an area surrounding Ruaha National Park in southern Tanzania. These fortified enclosures are built with chain-link-fence and are aimed to replace the traditional enclosure (known as a *boma*) built with acacia thorn branches (Lichtenfeld et al. 2015). We first implemented a before-after-control-impact (BACI) design (a.k.a., difference in difference) (Ferraro *et al.* 2019) to test the short-term impacts of the fortified enclosure intervention (i.e., 3 months; n=208 households). Next, using these short-term data, we conducted a cost-benefit analysis in terms of the expected economic impact of livestock lost to carnivores and the cost of building the fortified enclosures. Finally, we tested the hypothesis that fortified enclosures diminish in effectiveness over time as carnivores become habituated and depredation risk to all the household's livestock increases. We did this by utilising a long-term record of monthly monitoring data, including households with both traditional and fortified enclosures (n=758 households, 2010-2016). Findings provide actionable evidence on the impact of an intervention to inform conservation strategies supporting human-carnivore coexistence.

MATERIALS AND METHODS

Study Area

The study area is part of the Ruaha-Rungwa landscape, which covers over 45,000 km^2 and includes the c. 20,000 km^2 Ruaha National Park along with adjacent game reserves and community wildlife management areas (CWMAs). The MBOMIPA CWMA is a vital part of the Rungwa-Ruaha landscape, as it provides dry season habitat for many of Ruaha National Park's species (Dickman 2009). The climate in Ruaha-Rungwa is arid to semi-arid, with weakly bimodal annual rainfall averaging 600 mm (Fick and Hijmans 2017), peaking in December-January and March-April. The vegetation cover in the landscape is a mosaic of Southern Acacia-Commiphora bushlands and Central Zambezian miombo (Brachystegia-Jubelnardia) woodlands, riverine forests, and flood-plain grasslands. The protected areas are unfenced, allowing carnivores and other wildlife to use the surrounding community lands.

This study focused on 12 villages in Iringa Region located along the south-eastern border of the Ruaha National Park (Fig. 1). The MBOMIPA WMA acts as a buffer between the national park and adjacent village lands (Salerno et al. 2021). Farming, grazing and human settlements are all permitted on village land bordering the WMA. WMA communities depend on diverse livelihoods, including smallholder farmers and livestock keepers, the latter sometimes engaging in seasonal migration with their livestock. According to the last census (which was rather dated, from 2012), the study area had a total population of 36,258 people (NBS 2012), a smaller number of whom were livestock keepers. Although official censuses do not record the ethnicity of people living in the area, a survey conducted in the study villages identified six major tribes that depend primarily on livestock, of which Maasai and Barabaig represented over 80% of these pastoralist households (Ruaha Carnivore

Project, *unpublished data*). People from different ethnic groups are generally intermixed in the study villages, although members of the same ethnic group are often clustered in sub-villages. Hehe and Bena are usually located relatively close to the village centres, while Barabaig, Maasai and Sukuma tend to settle in adjacent, lower density areas.

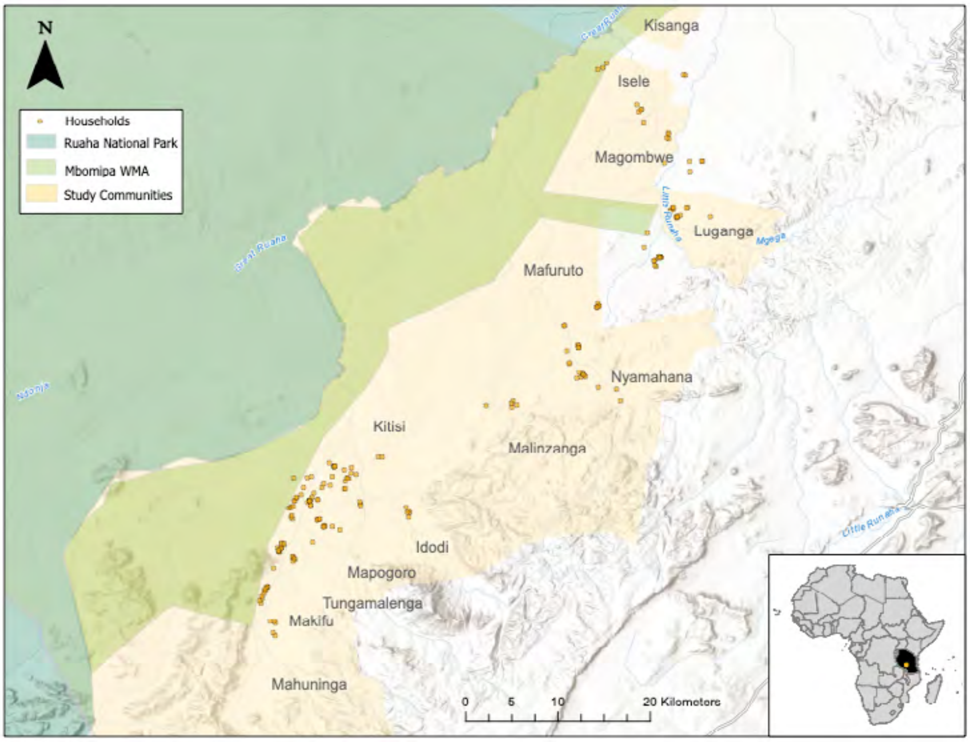

Figure 1. Study system in southern Tanzania. Livestock depredation data for the short-term analysis were collected from pastoralist and agropastoralist households (orange points) in communities (light yellow) adjacent to MBOMIPA Community Wildlife Management Area (light green) and Ruaha National Park (dark green). Data informing the long-term analysis were collected from households in these same study communities.

The Ruaha Carnivore Project and fortified enclosure intervention

Since 2009, Lion Landscapes (LL) (originally known locally as the Ruaha Carnivore Project, RCP) has been working with communities around Ruaha National Park to reduce human-carnivore conflict. Among other initiatives, LL facilitates the construction of fortified livestock enclosures, providing the materials and labour and subsidising the cost. Traditional livestock enclosures are built with acacia branches piled up to form a wall. Some households have a single enclosure for all their livestock, while others have several separate, smaller enclosures inside a compound (Fig. 2).

Figure 2. Livestock enclosures in the Ruaha-Rungwa Landscape. (a) Aerial image of a traditional household compound, showing thornbush livestock corrals and houses (image extracted from Google Earth Pro). Typically, small subdivisions inside the main thorn acacia wall are used to separate different ages or species of livestock. **(b)** Traditional enclosure **(c)** Fortified enclosure. Photo credits: Lion Landscapes.

The fortified enclosures are built either with metal or wooden poles and surrounded with 2.5 mm chain-link-fence with a height of 1.8 metres. The poles are fixed to the ground using concrete. The cost of building the fortified enclosure is subsidised at 75% by LL, with the remaining 25% being the responsibility of the livestock owner. The subsidised cost of an enclosure that uses two rolls of chain-link fence supported by metal poles is 170,000 TSH (c. US$ 98) and can protect up to 200 sheep and goats or 80 cows. If wooden poles are used, the subsidised cost of an enclosure of the same size is 75,000 TSH (c. US$ 43). The conversion rate used is 1 USD = 1,731 TZS which was the average conversion rate across the years included in this study.

Only one fortified enclosure is installed per household, and so households maintaining multiple enclosures typically use the fortified enclosure for the most vulnerable livestock (i.e., sheep, goats, and calves) while cattle remain in traditional enclosures. However, this situation is dynamic because some livestock can be seasonally moved to different locations in search of pastures, and the livestock are shifted between enclosures during the rainy season to prevent hoof infections.

Research design

To test the effectiveness of the fortified enclosure intervention, this study conducted two controlled natural experiments within a group of 13 villages. First, we examined the immediate impacts of fortified enclosures on livestock depredation during 6-month trial periods (i.e., 3 months before and 3 months after construction in households between January 2011 and January 2016), what we term the short-term analysis, using a BACI design. To do this, we paired treatment households where LL constructed a fortified enclosure with control households (i.e., neighbours) with only traditional enclosures. Households were selected for treatment from those who had requested a fortified enclosure and were located within the LL project region. Priority was given to households that had experienced recent carnivore depredation; therefore, treatment households were likely to have higher baseline rates of depredation than the population. Neighbour controls were identified as the 1-3 households nearest to the treatment households within c. 500 metres; neighbours served as controls and to observe possible spill over effects immediately following the fortified enclosure construction (i.e. if the construction of a fortified enclosure causes an increase or decrease in depredation at neighbouring households). We monitored livestock depredation in both groups during the 3-month periods before and after the target households received their fortified enclosure. The analysis utilised 100 treatment households (*n*=200 household-periods) and 108 control households (*n*=216 household-periods). We also conducted the cost-benefit analysis using these household data.

Further the study examined the long-term impacts of the fortified enclosures on livestock depredation by utilising monthly monitoring data of 758 livestock keeping households conducted by LL from 2010 to 2016. Households were selected for monthly monitoring as part of LL activities to monitor monthly livestock numbers and losses across the 12 study villages. The analysis utilised a sample of 121 treatment households (*n*=3,800 household-months, i.e. months when enclosures were monitored) and 637 control households (*n*=22,941 household-months).

Analysis

The multilevel (a.k.a, hierarchical; mixed, random, varying effects) statistical models was fitted to the short-term and long-term data to test for the effect of the fortified enclosure intervention on livestock depredation by large carnivores. Due to the over-dispersion of the livestock depredation outcome variable, both analyses implemented a negative binomial model structure with a logit link. We used the R package {glmmTMB} and the glmmTMB() model function, using the "nbinom2" family, which allows the variance to increase quadratically with the mean (Brooks *et al.* 2017). Because the study assume that monthly livestock depredation by carnivores is related to the number of livestock owned, we standardised the outcome variable by livestock owned using the offset() function within the linear predictor of model formula in the glmmTMB() call toR.

For the short-term, BACI, analysis, the model included varying, or random, intercept effects for community and household. We understand the varying intercept effects for households to control for non-independence of repeat monthly observations within each household, while community effects control for unobserved variance clustered or patterned spatially at the community level (Gelman and Hill 2007). The test for impact was conducted by estimating the binary effects for sampling time (before or after the intervention), treatment group (fortified vs. traditional), and their interaction, with the interaction being the term of interest when determining impact over time.

The cost-benefit analysis was applied only to the short-term, paired sample. The economic impact of livestock losses was calculated based on observed depredation and average values of livestock in local markets recorded by LL at the time of the study (cows, $360; sheep and goats, $45; donkeys, $150).

For the long-term analysis, in which the sample did not contain paired treatment and control groups, the model included the same varying effects structure with household and village varying intercepts. The model included fixed effects for treatment, wet season as a binary control covariate, and their interaction.

Model fit was assessed by examining QQ residual plots and plotting standardised residuals against rank transformed model predictions. We interpreted model results by plotting predictions and assessing estimates and 95% confidence intervals. Estimated marginal means plots were produced with the function emmip() from the R package {emmeans} (Russell V. Length, 2021), the coefficient plots were produced with the funcion dwplot() from the R package {dotwhisker} (Frederick Solt and Yue Hu, 2021) and the residual plots were produced with the package {DHARMa} (Hartig 2021). Data cleaning and preparation was performed using the package {tidyverse} (Wickham *et al.,* 2019). Analyses were performed using R version 4.2.3 (R Core Team 2023).

RESULTS

Livestock depredation

Livestock killed by carnivores per month per household during the three months before enclosure fortification averaged 0.21 and 0.11 in treatment and control households, respectively (Table 1). Rates decreased substantially in both groups following construction, to 0.01 and 0.04 in treatment and control households, respectively. During the 6-month intervention period, a total of 118 livestock were killed by carnivores among the 208 households sampled. Of those, 103 were killed during the three months prior to the intervention.

Table 1. Summary values from the short-term data record. Data are presented as types and numbers of livestock killed by carnivores in the two different types of households in the three months preceding and following the intervention.

	3 months before fortified enclosure				3 months after fortified enclosure			
	Cattle	Sheep/ goats	Donkeys	Avg. per month	Cattle	Sheep/ goats	Donkeys	Avg. per month
Treatment	4	61	0	0.21	0	3	0	0.01
Control	10	22	6	0.11	2	9	1	0.04

In the long-term monthly data record (2010-2016), depredation rates averaged 0.08 and 0.1 livestock killed per month per household for households with fortified and traditional enclosures, respectively (Table 2). A total of 2,686 livestock were reported as killed by carnivores in the 26,741 household-months observed. Sheep and goats were the most vulnerable to attacks representing 85% of the total livestock killed.

Table 2: Summary values of the monthly long-term data record. Data are presented as types and numbers of livestock killed by carnivores over the whole sampling period in the two different types of households.

	Total livestock killed	Number of months with attacks	Number of enclosure months	Number of cattle killed	Number of shoats killed	Number of donkeys killed	Average livestock killed/month
Fortified	336	124	3,800	69	261	6	0.08
Traditional	2,350	1,090	22,941	263	2,026	61	0.1

Short-term before-after-control-impact analysis

The BACI model estimated a significant impact of the fortified enclosure to reduce the probability of livestock depredation, as indicated by the coefficient of the interaction effect between treatment group and after-intervention (-1.90, 95% CI: [-3.60, -0.20]) (Fig.3a). This effect was estimated in addition to the already notable reduction in the probability of livestock depredation experienced by both control and treatment groups over the time period of the intervention (coef -0.99, 95% CI: [-2.03, 0.06]) (Fig.3a, Fig.4). In other words, livestock depredation declined in both fortified enclosure households and their neighbour-controls over the experimental period, but the BACI design attributed distinct impact of the fortified enclosures within the treatment group, equivalent to an 85% reduction in the odds of experiencing livestock depredation.

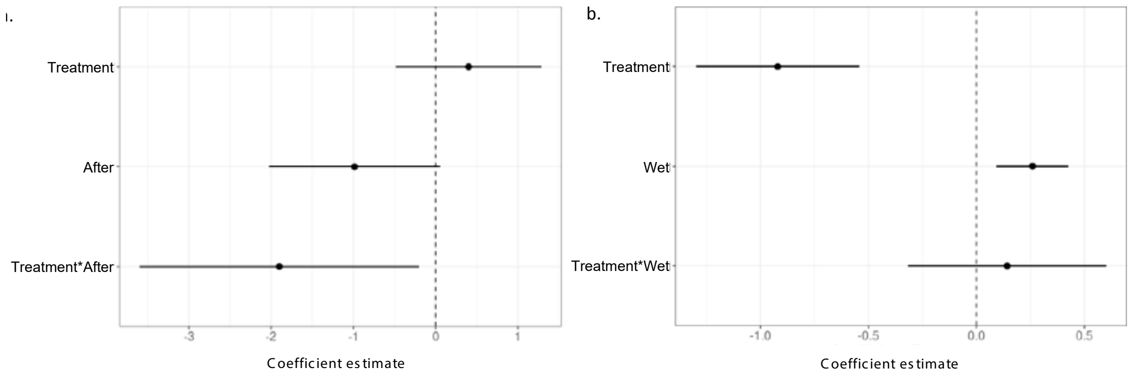

Figure 3. Statistical model results predicting livestock depredation. Coefficient estimates (log-odds) and 95% confidence intervals of (a) the short-term BACI model (b) and long-term model.

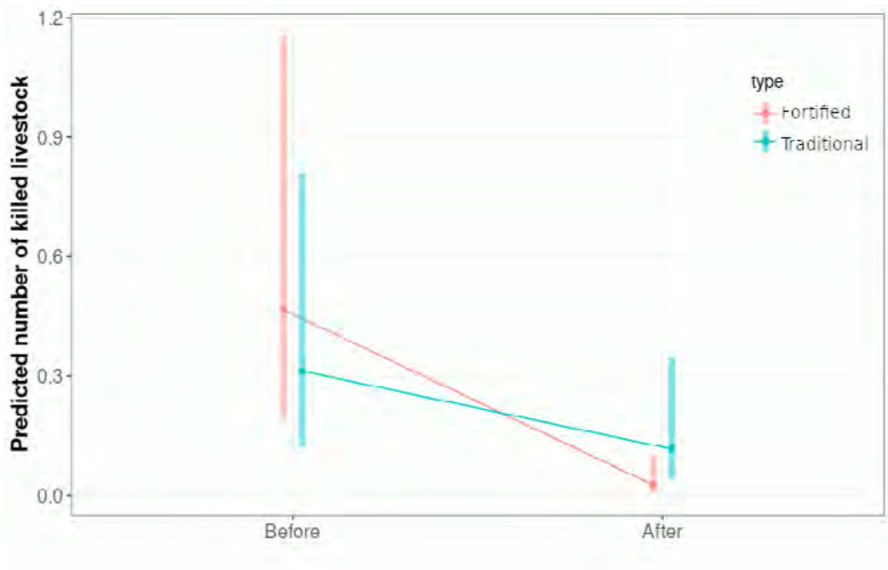

Figure 4. Estimated marginal means from short-term model. Model predictions for each level of interactions (i.e., the fortified enclosure vs. the traditional boma treatment levels) are plotted with 95% confidence intervals. Estimates illustrate the decline in depredations events during the 3-month treatment period in both groups, and also the greater reduction within the fortified enclosure treatment group compared to neighbour households with traditional enclosures.

Cost-benefit analysis

During the three months before the intervention in the short-term study, 35 households - out of the total sample of 208 - experienced total livestock losses equivalent to $4,185. Among these 35 households, the average loss incurred per household was $120 over three months ($40 per household per month). In this period prior to the intervention, across the whole sample, the average loss per household was $20 or approximately $7 per month.

Considering the latter as an estimated average monthly cost of depredation, it would take an average household approximately 6 months to recoup the cost of a two-wire enclosure built with wooden poles (2 years without the LL subsidy), and 14 months to recoup the cost a two-wire enclosure built with metal poles (5 years without the LL subsidy).

However, depredations are not evenly distributed among households. If we base our estimated average monthly cost of depredation on the households that suffered losses - $40 per month - it would take approximately one month to recoup the cost of a wire enclosure with wooden posts (4 months without the LL subsidy) and 2.5 months to recoup the cost of a wire enclosure with metal posts (10 months without the RCP subsidy).

Long-term control-impact analysis

The model fitted to the long-term data estimated a significant association of fortified enclosure with reduced probability of livestock depredation (-0.92 [-1.30, -0.54]) (Fig. 3(b)). This effect is equivalent to an 60% reduction in the odds of experiencing livestock depredation. Depredation was more likely in the wet season (0.26 [0.09, 0.43]). The interaction between both factors was not significant meaning the effect of the fortified enclosure was consistent across seasons

DISCUSSION

Across both short- and long-term analyses, fortified enclosures were effective at reducing livestock depredation by carnivores. The short-term analysis demonstrated the potential for dramatic initial reduction in livestock losses - from 65 to 4 individuals lost in our pre- to post-treatment period among treated households - while long-term analyses suggest these gains in protection endure for multiple years. Based on observed rates of livestock loss, and gains from protection, the cost of a fortified enclosure would be recouped within a matter of months, depending on type of construction and level of subsidy. The lifespan of both types of enclosures has been observed to be several years.

Interestingly, the short-term analysis indicates a reduction in the number of livestock killed during the experimental period in both treatment and neighbour, or control, households. This may be due to carnivore behaviour and changes in predation dynamics linked to prey availability or related processes, although the BACI design still identifies a positive impact of fortified enclosure. Alternatively, construction of fortified enclosures may have a beneficial spatial spillover effect, such that carnivores experience fortified enclosure construction as a disturbance and avoid the larger area, including neighbouring households with traditional enclosures. This pattern has been observed in other systems under a similar intervention (Lichtenfeld *et a*l. 2015). If a previously weak enclosure, which may have attracted carnivores as a rewarding resource, was improved, then the carnivores may stop coming to the household area. Further research is necessary to test for positive or negative spillover effects, including how dynamics change over time.

Despite being attacked less frequently, households with fortified enclosures still experienced livestock depredation. Consistent with traditional practices of maintaining multiple enclosures, households typically keep livestock in traditional enclosures alongside the fortified enclosure, and data do not allow for distinguishing between attacks inside versus outside the fortified enclosures in the same compound. Anecdotally, only leopards have been known to attack fortified enclosures in the study area, as they can climb over and out of the fencing carrying a goat or sheep. This is similar to what Ogada et al. (2003) observed in Kenya. On a few occasions, spotted hyenas have been observed to crawl under the wire, but this is usually due to inadequate maintenance of the enclosure. The widespread practice of keeping the most vulnerable livestock - sheep, goats and calves - inside the fortified enclosure could in part explain the substantial reduction in depredation shown here, and as suggested in other studies (Lichtenfeld *et al.* 2015, Weise *et al.* 2018, Lesilau *et al.* 2018, Stutton *et al.* 2017).

Notably, negative attitudes are not always correlated with direct livestock losses caused by carnivores (Dickman 2010), and other factors need to be considered when evaluating the effectiveness of fortified enclosures in mitigating human-carnivore conflicts. In Ruaha, despite the relatively low probability of attack at households (~0.05 per month in our long-term data), 94% of respondents reported a problem with at least one species of carnivore (Dickman *et al*. 2014). It is the attitudes regarding tolerance of carnivores generally, and not the impact of fortified enclosures or other mitigation measures, that will influence negative outcomes for carnivores (Treves & Bruskotter 2014). Indeed, perceptions of conservation efforts influence relationships among people and carnivores more broadly (Bruskotter & Wilson 2014). A study in northern Tanzania found that fortified enclosures are perceived by 97.7% of respondents to be effective (Mkonyi *et al*. 2017). This *perceived effectiveness* can be as important as *functional effectiveness* in determining the success of a conflict mitigation intervention if reducing human-caused carnivore mortality is the primary aim (Ohrens *et al.* 2019).

Importantly, there are hidden costs that livestock owners incur in order to prevent attacks on traditional enclosures that are not easily included in a cost-benefit analysis. For example, traditional acacia-thorn enclosures need to be constantly maintained to limit gaps that make them vulnerable to attack by hyaenas, and people typically sleep with the small stock to prevent such attacks (Dickman, unpublished data). As more children are attending school, making these enclosures safe with reduced labour availability is becoming an increasingly challenging task for many households. Reducing depredation through fortified enclosures can help reduce the indirect and opportunity costs of livestock guarding and human-wildlife conflict, which can be significant for vulnerable households (Ford et al. 2022).

A similar study in northern Tanzania found that predator-proofing of livestock enclosures was effective at reducing losses and was therefore seen as one of the most highly valued conflict mitigation interventions by livestock owners (Lichtenfeld *et al.* 2015). In Ruaha, it has proven to be an effective tool to diffuse conflict when a household has suffered repeated attacks by carnivores. In landscapes where organisations work alongside communities to reduce conflicts, programmatic approaches typically employ multiple strategies, and it is important to consider human dimensions of conflict when evaluating the effectiveness of such interventions (Dickman 2010).

The primary limitations of this study are in the short-term analysis, with two main potential sources of bias. The first is selection bias due to the non-random sampling of households receiving the fortified enclosure treatment. Because building an enclosure incurs a cost for the livestock owner, the sample could be biased towards households that have experienced recent attacks and therefore view the greatest benefit from reduced losses. This seems likely given the higher monthly rates of livestock depredation in target households (0.21) compared to their neighbour controls (0.08). This could lead to an over-inflated effect in the short term effectiveness. The second relates to possible confounding factors. The distance to the protected area could affect the probability of carnivore attacks: however, Dickman (2010) found no significant decline in large carnivore occurrence with distance from the RNP in the study area. Additional factors such as household guarding behaviour or maintenance of enclosure could also influence depredation outcomes. Also, the village was included in the analysis as a possible control for these natural variables.

CONCLUSION

From the results presented above, it is recommended that, livestock keepers and conservation managers in similar systems invest in fortified enclosures as a tool to promote coexistence with carnivores and reduce retaliatory killings. Depending on the local depredation rates and frequency, subsidising the building costs can be used as a tool to incentivise construction of fortified enclosures, particularly among livestock keepers who have not suffered recent attacks. The study recommend including stakeholder perceptions in the evaluation process of interventions aimed at reducing human-wildlife conflict, and such efforts must be attentive to the local institutional environment and evolving community-based conservation governance (Sills and Jones 2018, Salerno et al. 2021b). These findings underscore that future evaluations must implement controlled experimental designs in order to assess impacts and inform adapted programmatic priorities (Ferraro *et al.* 2019).

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SOCIOECONOMIC DRIVERS FOR HUMAN WILDLIFE CONFLICT IN COMMUNITIES LIVING ADJACENT TO PROTECTED AREAS IN RUAHA - MIKUMI LANDSCAPE, TANZANIA

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ABSTRACT

Socioeconomic drivers for Human Wildlife Conflict (HWC) was studied in communities adjacent to Ruaha - Mikumi landscape in Morogoro and Iringa regions. Four Districts facing HWC challenges from the two regions were selected purposively and a total of 24 villages were visited and qualitative data collected. Secondary data on hydrology were collected from Rufiji Basin Authority. Remote sensed data for rainfall, human population, and wild-fire for the past eleven (11) years (2010 - 2020) were used.Results showed that the amount of rainfall varied with districts in the landscape and years ($P<0.01$). Water flow rate was influenced by month and year, higher flow rates were experienced in April, May, March, and February ($P<0.05$) and low rates were measured in October and November. It was further noted that permanent flowing rivers are mostly passing through the villages leaving the protected areas with river and tributaries that are seasonally flowing. There were variations ($P<0.01$) in burned area between years and study districts. It was revealed that wildlife loved crops and alcohol making attracts wildlife to the homesteads, thus, increasing HWC. Most of the study villages had Land Use Plans (VLUP) however, no adherence to the VLUP. Human population increased tremendously in the landscape where in 2010 the landscape hardly had 220,000 people inhabiting the area, in 2020 the number increased 4 folds with the population of 920,000. It was generally concluded that rainfall influence water flow rate in various rivers in Ruaha Mikumi landscape, however, water abstraction upstream restricted water availability downstream forcing wildlife to seek water outside protected areas. Human population increase adjacent to protected areas resulted into destruction of historical wildlife habitats. Haphazard establishment of villages in wildlife areas has accelerated human wildlife conflict. Growing elephant loved crops around homesteads and making of fermented alcohol increase elephant raiding incidences.

Key Words: Human wildlife conflict, conflict causes, Coexistence

INTRODUCTION

The current global wildlife extinction rates exceed natural rates by three or four orders of magnitude (Lawton and May 1995), with large proportions of higher taxa considered at risk (Vié et al. 2009). The majority of the world's terrestrial area, about 84% of land surfaces outside Antarctica, has been directly modified by expanding land uses, and a fifth to a quarter of the world's terrestrial primary productivity is consumed by humans (Imhoff et al. 2004; Haberl et al. 2007). Habitat loss has contributed to the decline of at least 85% of amphibian, bird, and mammal species currently threatened with extinction (Baillie et al. 2004). By a vast margin, agricultural land uses are the most common cause of habitat loss around the world, and may be set to expand considerably (Tilman et al. 2001).

Surveys suggest that over 65% of the original wildlife habitat in Africa has been lost as a result of agricultural expansion, deforestation, and overgrazing, which have been fueled by rapid human population growth and poverty (Kiss 1990). The trend of wildlife habitat loss has been increasing over time (Kideghesho, 2015; Kija et al., 2020) with varying rate of loss in different parts of Africa. According to IUCN (1990, 1994), the wildlife habitat loss in Kenya was 67% while in Ethiopia, the country which was once heavily forested with about 40% of its total area covered by dense forest has more alarming situation because at present only 2.7% of the total area is forested (Sarunday and Muheto, 2000). In the year 1986, Tanzania was reported to have lost 43% of the original wildlife habitat converted to other human uses (Kaswamila, 2009). Kideghesho (2015) reported that Tanzania was losing an average of 403,350 ha annually which accounted for a total loss of 19.4% equivalent to 8,067,000ha of the forest cover. URT (2014) reported a current forest cover loss of about 38% and predict the total country forest loss in the next 50 to 80 years if no intervention is done. Human population increase from 12.3 million in 1961 to 44.9 million in 2012 and 61.7 million in 2022 with annual growth rate of 3.7% (NBS, 2012) coupled with poverty pose a great challenge to wildlife conservation in Tanzania. Destruction of wildlife areas through settlement establishment, and cultivation has accelerated Human Wildlife Conflict in Tanzania. Wild animals especially those with relatively larger home range like elephants are spending more time in village-land and some making settlement in their historical areas. Agricultural expansion and unplanned irrigation schemes upstream has resulted into rivers that used to flow water permanently becoming seasonal, thus, compelling wildlife to get out of protected areas in search of water, resulting into human wildlife conflict manifested through human and domestic animal deaths, human injuries, and crop raiding and death of wildlife that depend on water for their survival or through retaliatory killing. Between 2012 and 2019 a total of 1,069 human deaths, 642 human injuries, 792 livestock death, and 41,404 acres of crops damaged were reported (URT, 2020 - 2024). Parallel to this loss the Government of Tanzania paid a total of Tshs 4,670,555,300 equivalent to USD 2,030,676 as a consolation to wildlife affected people in the span of four years (URT, 2020 - 2024). The HWC in Tanzania is increasingly resulting into food insecurity, human insecurity, and Government loss through consolation scheme. The purpose of this study was to assess the socio-economic drivers that leads to human wildlife conflict in Ruaha - Mikumi Landscape and propose the possible mitigation measures.

METHODOLOGY

Study area

This study covered two regions namely Iringa and Morogoro. In Iringa region two districts namely Iringa rural and Kilolo districts were involved and in Morogoro region Kilosa and Kilombero districts were involved. The two regions are bordering Ruaha, Mikumi, Udzungwa and Nyerere National Parks. Ruaha National Park is on southern highlands characterized by water catchments that make a flow of rivers and their tributaries where 24 water gauging stations namely Chimala, Great Ruaha, Hagafiro, Kihansi, Kigogo, Ruaha, Kimani, Kizigo, Little Ruaha, Luipa, Lukosi, Lumemo, Mbarali, Mnyera, Mpanga, Mtitu, Mwega, Ndembera, Ruhuji and Yovi are located. These rivers drain its water to Mikumi, Kilombero valley and down to Rufiji river through Nyerere National Park. In this study, this Landscape covering and area from Ruaha down to Nyerere National Park is referred to as Ruaha - Mikumi Landscape (Figure 1).

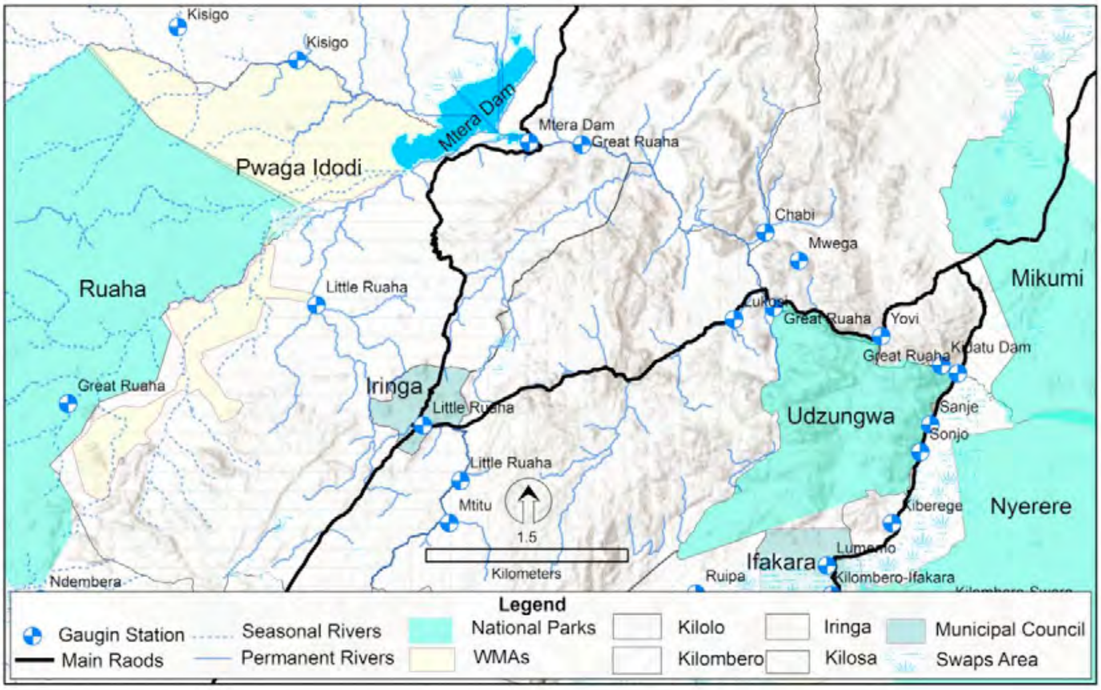

Figure 1: *Ruaha - Mikumi Landscape covering Ruaha, Mikumi, Udzungwa and Nyerere National Parks*

Data Collection

Water flow rate Water flow rate data were obtained from Rufiji Basin office in Iringa, Tanzania an Authority governing water use in the landscape. It manages all rivers and their tributaries draining water into the four major rivers namely Great Ruaha, Kilombero, Luwegu, and Rufiji which eventually pour its water in Indian ocean. The water flow rate for the past 11 years (2010 - 2020) were measured in 24 gauging stations of the rivers in the landscape (Table 1).

Table 1: River and tributaries where water gauging station for flow rate was measurements were done for the past 11 years (2010 - 2020) in Rufiji basin, southern Tanzania

ID	River Name	River Code	Status
1	Chimala	R1	Seasonal
2	Great ruaha at Salimwani	R2	Seasonal
3	Great ruaha at Msembe	R3	Seasonal
4	Great ruaha at Nyaruhanga	R4	Seasonal
5	Hagafiro river at Hagafiro	R5	Permanent
6	Kihansi river at Lutaki	R6	Permanent
7	Kigogo ruaha at Lungema	R7	Seasonal
8	Kimani	R8	Seasonal
9	Kizigo river at Kigogo	R9	Seasonal
10	Little ruaha river at Makalala	R10	Permanent
11	Little ruaha river at Mawande	R11	Permanent
12	Little ruaha river at Ndiuka	R12	Permanent
13	Luipa river at Mbingu	R13	Permanent
14	Lukosi river at Mtandika	R14	Seasonal
15	Lumemo river at Kiburubutu	R15	Permanent
16	Mbarali river at Igawa	R16	Permanent
17	Mnyera river at Taveta	R17	Seasonal
18	Mpanga river at Mpanga mission	R18	Seasonal
19	Mtitu river at Mtitu	R19	Permanent
20	Mwega river at Malolo	R20	Permanent
21	Ndembera river at Ilongo	R21	Permanent
22	Ruhuji river at Kifunga falls	R22	Seasonal
23	Yovi river at Yovi	R23	Seasonal
24	Mgeta river at Mgeta	R24	Seasonal

Rainfall, human population, Temperature, and wild fire incidences

Remote sensed data for rainfall (CHIRPS), population density (Land-Scan Sat), temperature (MODIS MOD11C3), and wild-fire incidences (MCD14ML, MCD64A1) for the past 11 years (2010 - 2020) were used.

Qualitative data

Direct observation from the four (4) districts, 6 villages each making a total of 24 visited villages facing HWC in Ruaha - Mikumi landscape was done. Environmental degradation activities were observed and recorded.

Statistical data analysis

The secondary data obtained were analyzed using SAS (version 9.1) software. Analysis of Variance (ANOVA) was used to determine the influence of drivers of Human Wildlife Conflict (HWC) over a period of time, the driver for HWC was considered significant when $P<0.05$.

Mean comparison between study districts and years was done using Duncan Multiple Range Test (DMRT) and results are presented as Mean ± SD.

RESULTS AND DISCUSSION

Drivers of human Wildlife Conflict in Ruaha - Mikumi Landscape

Rainfall and temperature

Climatic factors such as rainfall, influence water and herbage availability that impose wildlife distribution. Generally, the amount of rainfall varied with districts in the landscape and years ($P<0.01$). Kilombero district received highest amount of rainfall (Table 1) that did not differ statistically with the rainfall received by Iringa rural and Kilosa districts ($P>0.05$), however, Kilolo district received relatively lowest amount of rainfall ($P<0.05$). Generally, the amount of rainfall in the landscape for the past 11 years (2010 - 2020) exhibited an increasing trend with a minimum rainfall of 650mm in 2010 and maximum of 1,250mm in 2020 (Figure 2). This data demonstrates that movement of wildlife outside the protected areas is not driven by rainfall which depicts herbage availability, but rather, wildlife moving to their historical areas searching for ecological niche (such as mineral lick, calving areas, refugee, etc). Converting these areas into settlement, agricultural fields definitely denies wildlife with their necessity, hence, will keep on coming to the area, thus resulting into continuous conflict.

It is clear from the rainfall pattern that districts with high rainfall are favourable for agriculture and livestock keeping, attracting immigrants of other ethnic groups to the area. Kilombero, Iringa Rural and Kilosa districts are highly invaded with agro-pastoralists claiming land for agriculture and pastoralism. Nindi *et al* (2014) reported three main agro-pastoralists ethnic groups including Sukuma, Masai, and Barbeig immigrating to the Kilombero Valley Flood Plain (KVFP) to undertake grazing, agriculture and fishing. These ethnic groups not only do the mentioned activities but also do illegal harvesting of wildlife as such. The KVFP harbors about 75% of the world Puku antelope population. However, the population of the antelope has declined dramatically as people started immigrating into the area in 1990s. In 1998, Puku population was estimated at 50,000 individuals, fifteen years later (2014) the puku population declined tremendously to 3,145. The 2018 census in the same area estimated further decline of Puku population where an estimate of 1,579 puku was recorded (TAWIRI, 2018). The decline of puku antelopes in the area depicts decline of other wildlife species in the landscape. This should be taken as a wake up bell as immigration of agro-pastoralists in the landscape might wipe out wildlife species in the landscape if no deliberate interventions will be taken.

Looking at the environmental temperature trend, a decrease by 2°C from 31°C in 2010 to about 29°C in 2020 (Fig. 2) was realized. This implies that the water loss through evapo-transpiration was minimal making water flow in the rivers (Fig. 3) in Ruaha - Mikumi landscape more available for use by wildlife down stream. Due to increasing rainfall in the landscape, forage availability to wildlife could not be a problem driving wildlife to get out of protected areas.

Table 2: Mean rainfall in the four districts in Ruaha - Mikumi landscape experiencing human wildlife conflict (2011 - 2020)

District	Mean rainfall ±SD	Significance Level
Kilombero	1484.45 ±398.23[a]	NS
Iringa Rural	1288.30 ±185.89[a]	NS
Kilosa	1142.72 ±277.77[a]	NS
Kilolo	702.74 ±143.57[b]	P<0.05

Note: *Means bearing different superscript along the same column are statistically different(P<0.05).*

Water flow rate

Water flow showed availability of water from the source (catchment) downstream for use by other users including wildlife. However, as expected water flow rate was influenced by month of the year (P<0.05) where higher flow rates were experienced in April, May, February and March (P<0.05) and low water flow rate were measured in October and November characterized by little or no rains. The reason of higher water flow rates in April, May, February and March could probably be due to the fact that February - May is a long rain season with most if not all rivers flowing water, October - November is a characterized with low or no rain, thus low water flow rates (Table 3).

Apparently rainfall that influence river water flow rate varies with years, this study showed significantly highest water flow rates in the year 2020 where a mean flow rate of 47.4 m3/sec was recorded, low water flow rates were recorded in the years 2013 and 2011 with 9.7m3/sec and 9.9 m3/sec respectively (Table 3). Apart from seasonal and year water flow rate variations, human activities such as irrigation, hydroelectric power generation can influence water availability to other users down-stream. Results in this study showed that out of the 24 river water gauging stations only eleven (11) stations flew water permanently (Table 1 & 3).

Table 3: Mean water flow rates (m3/sec) variation by month, year and river water gauging points in the Ruaha - Mikumi Landscape measured from 2011 - 2020

Month	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Flow	13.3[c]	30.5[b]	39.1[a]	39.3[a]	24.9[b]	14.0[c]	9.7[d]	7.0[d]	5.2[d]	4.3[e]	3.9[e]	6.7[d]
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**		
Flow	9.9[c]	10.3[c]	9.7[c]	16.7[b]	10.6[c]	19.7[b]	11.5[c]	14.7[bc]	14.2[bc]	47.4[a]		
Station	**R5**	**R13**	**R11**	**R12**	**R6**	**R16**	**R15**	**R21**	**R10**	**R19**		
Flow	49.1[a]	27.6[b]	23.1[b]	16.9[c]	15.8[c]	11.4[c]	8.7[d]	5.6[d]	3.3[e]	3.1[e]		

Note: *R5 - Hagafiro; R13 - Luipa; R11 - Little Ruaha at Mawande; R12 - Little Ruaha at Ndiuka; R6 - Kihansi at Rutaki; R16 - Mbalali; R15 - Lumeo; R21 - Ndembera; R10 - Little Ruaha at Makalala; R19 - Mtitu*

Note: Means bearing different superscript along the same row are statistically different(P<0.05).

Generally, the average water flow rate showed an increasing trend from 2011 to 2020 (Figure 3). However, that increase in water flow rate does not imply that water was available to wildlife down stream. The rivers that used to be permanently flowing in Ruaha - Mikumi Landscape have been impacted by injudicious agricultural irrigation scheme upstream by abstracting water and diverting to paddy farms and hampering the water flow, making the rivers in the parks to be seasonal. A good example is the Great Ruaha river that pass through Ruaha National Park and the only reliable source of water to wildlife in the park has been seriously impacted by irrigation scheme and making it flow only during wet season. This has resulted into serious impact to wildlife in the Ruaha National Park, sometimes causing massive death to some animal species especially hippo and crocodiles that depends on water to survive. Little Ruaha feeds its water to the Great Ruaha river, but water flow rate upper stream at Mawande (R11) was significantly ($P<0.05$) higher than that measured along the same river down stream to Ndiuka (R12) and Makalala (R10) (23.1, 16.9 and 3.3 respectively). Basing on this fact there is likeliness that wildlife especially elephant dispersal into the village area primarily in search of water which consequently results into conflict with human living adjacent to the protected areas.

The permanent flowing rivers are mostly passing through the villages leaving the protected areas with river and tributaries that are seasonally flowing (Figure 1). This compel wildlife to go out of protected areas to the village land where rivers are flowing to obtain water for drinking and wallowing.

Apart from wildlife causing conflict with human being, it has been reported that water use conflict is manifested through livestock killing especially at the common water points when elephants drinking time coincide with that of livestock. Between 2012 - 2019, in Tanzania, a total of 792 livestock were killed by wild animals including elephant mainly when were crossing the river, watering edge where elephant drug livestock out of water causing injuries and sometimes death to livestock (URT, 2020 - 2024). Alternative watering points for livestock or wild animal is critical to reduce water use conflict in the Ruaha - Mikumi landscape.

Wildfire trend

Wildfire in protected areas are mainly resulted from unmanaged fire either set during needs for improving pasture quality, killing parasites, facilitating wildlife hunting, honey collection, charcoal burning, mining, pit sawing, grazing, opening farms, and wildfire attributed to pedestrians (Kidegesho, 2015). Although many animals in fire-prone habitats are able to detect and avoid wildfires, fires still pose direct threats to wildlife (Engstrom 2010, Nimmo et al 2021), including exposure to extreme heat and smoke. Yet, the impacts of wildfire smoke on the health and behavior of wildlife are largely unknown (Hovick et al 2017, Lee et al 2017, Erb et al 2018, Geiser et al 2018). One of the effect of wildfire burning forest is destruction of ecosystem services like denial of food and shelter for wildlife and render them get out of the wild to villages to seek for alternative survival measures, thus results into conflict with neighbouring communities.

In Ruaha - Mikumi landscape there were variations (P<0.01) in burned area between years (Figure 4) and study districts (Table 5). Highest (P<0.05) area was burnt in 2010 where a total of about 14,680 ha were burnt, and lowest wildfire was experienced in 2017 where an area of about 4,500 ha was burnt (Figure 4). Highest burnt area was noted in Iringa rural followed by Kilombero, Kilolo and Kilosa with an area of 3,518.1, 2,433, 2,088.5, and 1,819.6 ha burnt respectively (Table 5). FAO, reported that between 1990 and 2010, Tanzania lost an average of 403,350 ha of forest per annum due to wildfire. This habitat loss for wildlife probably augment the out going of wild animals in communities for search of safe areas thus, resulting to increased human wildlife conflict. Control on wildfire and reduced destruction to forest and wildlife habitats could reduce human - wildlife conflicts.

Table 5: Mean burned areas in different districts in the Ruaha - Mikumi Landscape measured from 2010 - 2020

District	Mean burned area(ha)	Significance Level
Iringa rural	3518.1[a]	P<0.05
Kilombero	2433.0[b]	P<0.05
Kilolo	2088.5[c]	P<0.05
Kilosa	1819.6[d]	P<0.05
Total	**9,358**	

Note: *Means bearing different superscript along the same column are statistically different (P<0.05).*

Cultivation of elephant loving crops around homesteads

Like any other communities, villages adjacent to protected areas grow crops near by homesteads. Fruits like mangoes, jackfruit, etc have been reported to be preferred by elephants (Plate 1). Elephant can smell food and water up to 20 km away (*Science.org*), thus, during fruits ripening season elephants attacks villages in search of fruits. It has been reported that elephant can break house (Plate 2) looking for fruits, fermented alcohol, or some preserved foods like dried sweet potatoes. Coexistence between human and elephant can be possible if such types of food, fruits, and alcohol are avoided.

Adherence to Village Land Use Plan (VLUP)

Village Land use Plans as an outcome of a participatory and systematic assessment of physical, ecological and socioeconomic, reflect on current and future needs of the community (FAO, 1993). The government of Tanzania instituted participatory village land use plans (VLUPs) through the Village Land Act No. 5 of 1999 and Land Use Planning Act No. 6 of 2007. The VLUPs were adopted across sectors with the recognition of its problem solving ability through grassroots involvement in planning and decision making (NLUPC, 1998). The expectations of that were to facilitate allocation of land according to land use needs, overcoming land use conflicts, and creating a basis for issuing long-term leases to villagers among others (NLUPC, 1998).

Most of the study villages have VLUP with well demarcated land use zones. The difficulty part is adherence to the VLUP mainly due to various reasons that includes land use conflict, encroachment, invasion contrary to the planned objective(Kaswamila and Songorwa, 2009; Toillier et al., 2011). In Tanzania, in spite of established land use plans, complexities have been realized over zoning of land use for mobile land users such as pastoralists, hunters and gatherers (UCRT, 2010; Mwambene et al., 2014).The challenge comes when pastoralist are turning into agro-pastoralists, undertaking agriculture in pastoral land as livestock alone can not fully support household demands.

It was noted that crop cultivation is done very close to the river banks, forcing wild animals to raid the crops as they come down the river in search of water. National Environmental Management Act (2004) directs human activities to take place 60m away from the river bank. It is a pity that agriculture takes place down to the river banks to get reliable water for irrigation or use the moisture contained in the soil near by the river that ensure crop survival even in rain shortage period. Agriculture undertaking near by the rivers results into destruction of riparian forest which in most cases provide food for some wildlife like primates. Denial of the food to primates due to riparian forests destruction results into increased incursions of human primate conflict.

Human population Density and Cropland Size

The current human population in Tanzania mainland is 59,851,347 and 1,889,773 in the isles making a total of about 61.7 million people. When these populations are compared with the population in 2012, there is a average growth rate of 3.2% and 3.7 for Tanzania mainland and Zanzibar respectively (NBS, 2022). The human population will keep on growing as years goes unless a special family planning interventions are done. Mwakisisile and Mushi (2019) predicts a human population 2035 to be 87,538,767. Considering the surface area of Tanzania of 947,300 sqkm with a human carrying capacity of 2,976,857,550, the population will still continue to grow faster since it is far beyond its limiting value.

In 2010 the Ruaha - Mikumi landscape hardly had 220,000 people inhabiting the area. By the year 2020 the number of people increased by four fold with a population of 920,000 (Figure 5). This rapid increase in human population has resulted into two major conservation challenges:

a: Opening up crop-fields by clearing wildlife areas

Human population increase goes hand in hand with an increase in household food requirements. Most of small subsistence farmers practice extensive farming system where little or no agricultural inputs are applied, consequently crop yield density is very low. When lower crop yields are realized, shifting cultivation is practiced and eventually leaves a big change in land cover of a sizable part of the land. Figure 6 demonstrates the land cover change in the Ruaha - Mikumi Landscape for the past 11 years (2010 - 2020).

It is obvious that a change in land cover of the landscape could be influenced by deforestation for extensive livestock keeping leaving a big part of the land covered with grassland and woodland. Agro-pastoralists prefer grassland for livestock feed availability and reduction in tsetse flies infestation that affects their livestock. It is unfortunate that about 50% of forested land falls under village and general land with unclear management regime, thus, being subjected to severe deforestation and degradation (Kideghesho, 2015).

Due to fertile arable land and reliable rainfall nearby protected areas there have been immigration of people especially pastoralists in these districts adjacent to protected areas resulting into rapid population increase and thus, converting forests into woodland (Kideghesho, 2015). However, practicing low cropping (Figure 5) as communities adjacent to protected areas are more discouraged to cultivate crops as crops are frequently raided by wildlife and find alternative ways of living mainly through dependence on natural resources and other ecosystem services. It has been reported that in Africa, the livelihood of over 62% of 1.2 billion people depend directly on biodiversity as well as ecosystem services. However, this should be checked as the imposed demand will negatively affect biodiversity through habitat conversion, over-harvesting, and overgrazing (TAWIRI, 2022).

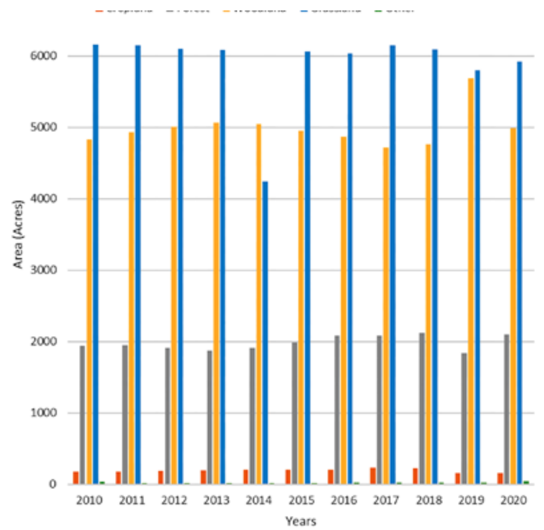

Figure 6: Land cover in Ruaha - Mikumi Landscape for the past 11 years (2010 - 2020)

Table 6: Land cover change of four districts adjacent to protected areas in Ruaha - Mikumi Landscape.

Land cover(km2)	District			
	Kilolo	**Kilosa**	**Kilombero**	**Iringa rural**
Forest	2842.8[a]	2731.2[b]	2129.1[c]	228.7[d]
Woodland	4122.1[c]	5148.4[b]	8499.6[a]	2176.2[d]
Grass land	2039.6[c]	3732.7[b]	2280.4[c]	15514.5[a]
Crop land	222.1[b]	267.0[a]	81.4[c]	191.9[c]
Others	0.0[c]	6.7[c]	19.4[b]	62.9[a]

Note: *Means bearing different superscript along the same row are statistically different($P<0.05$).*

b: Increase in number of livestock

The increase in pastoral communities household size inevitably results into increase in livestock number to tarry with the increased household demand. In areas where the pastoral communities used to exist, started practicing agro - pastoralism as livestock alone does not suffice the increased household food demand. Increased livestock numbers coupled with increase in human population size resulted into emigration to other areas searching for arable land for cultivation and forage for their livestock. It has been observed that more influx is in villages that borders with protected areas including villages falling in Ruaha - Mikumi landscape. Jones et al. (2009) reported a rapid immigration of people and livestock from all over Tanzania in recent decades to Kilombero and Kilosa districts that led to a widespread land use changes, resulting in increased HWC including loss of crops, human deaths and increased poaching. The people and livestock influx has been witnessed in most places particularly in communities adjacent to protected areas with big idle pieces of land. The spontaneous people movement without restriction and right to settle anywhere coupled with unscrupulous village leaders offer these village wildlife conserved lands to agro-pastoralists who converts the forested area for agriculture and livestock keeping. Denial of wildlife with their natural historical habitats compel wildlife to outspread in the villages and increase conflict.

CONCLUSSIONS

- There have been an increasing trend in rainfall and decreasing temperature trend in Ruaha - Mikumi Landscape, frequent wildfire incidences, and increased water flow rate in the landscape in the past 11 years.
- Most of permanent water flowing rivers in Ruaha - Mikumi Landscape are found outside protected.
- Rivers tributaries passing through protected areas turned to be seasonal due to increased human activities near or around water catchments.
- Human population increase adjacent to protected areas has resulted into opening up more farms and increased livestock numbers to suit the household demand consequently destructs wildlife habitats, eventually increase human wildlife conflict.
- Haphazard establishment of villages in wildlife areas (wildlife corridors, migratory routes, buffer zones) due to political influence has accelerated human wildlife conflict.
- Rational water use upstream is important to ensure water flow downstream that allows wildlife to access water in protected areas.
- Growing elephant loved fruits around homesteads increase elephant raiding incidences in villages contiguous to protected areas.

RECOMMENDATIONS

- Rufiji Basin Authority should follow-up and ensure judicious use of water upstream to allow water flow downstream and ensure availability of water in protected areas.
- Man-made water bodies should be developed to ensure availability of water in protected areas that will decelerate wild animals getting out fetching for water resulting into HWC
- Livestock movement should be checked to reduce the influx of domestic animals in community land adjacent to protected areas.
- Resettlement of people who immigrated in the KVFP is imperative to reduce the human activities pressure in the area and rescue the puku antelopes and other wildlife
- Education on Human - Wildlife Coexistence, and family planning is critical.

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VULTURES POPULATION SEASONAL VARIATION IN MAKAO WILDLIFE MANAGEMENT AREA, MEATU DISTRICT IN SIMIYU REGION: AN INSIGHT FOR CONSERVATION EFFORTS

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ABSTRACT

The drastic decline of all species of vultures during recent decades in Africa is a well-known fact. Poisoning, habitat destruction, and traditional uses have been considered among the major factors behind the vulture population crisis. However, limited information is available on their population status and distribution range around the world. For effective conservation activity, regular updates to monitored data and population estimates are inevitable. The project aimed to establish baseline data on the current population status through population counts and distribution patterns, with the objective of identifying vulture species and their diversity at Makao WMA. The study was conducted in Makao WMA in two seasons: wildebeest migration (December–April) and non-wildebeest migration (May–November). The road count method was used for the survey within 9 developed transects. Four different species of vultures, named the White-backed Vulture (150), Ruppell's Vulture (37), Lappet-faced Vulture (22) and Palm-nut Vulture (4), were recorded during wildebeest migration season. The findings show that Transect 7 was more diverse (H = 0.84) compared to Transect 8 (0.07). On the other hand, for non-wildebeest migration, only Ruppell's Vulture (1) and Lappet-faced Vulture (2) were observed in transects 3 and 8, respectively. The findings show that Transect 3 was more diverse (H = 0.37) compared to Transect 8 (0.27). As we targeted surveying in the two seasons during wildebeest migration and non-wildebeest migration, the counts and frequencies of vultures after wildebeest migration look smaller than those during wildebeest migration. The results imply that the movement of wildebeests has significant influence on the movement and distribution of vultures in Makao.

Key-words: Conservation, Seasonal Distribution of Vultures, Wildebeest migration.

INTRODUCTION

Old World vultures (belong to the family Accipitridae, do not have a powerful sense of smell and thus locate their meals by sight) are the most endangered group of birds in the world (Buechley & Ekerciolu, 2016a, 2016b), with 80% of species experiencing global population declines and 75% of species being listed by the International Union for the Conservation of Nature as either endangered or critically endangered (IUCN; McClure et al., 2018). It is widely accepted that breeding populations of vulnerable vultures need to be regularly monitored in order to effectively carry out focused conservation operations in significant zones across their ranges (Margalida & Ogada, 2018; Santangeli et al., 2019). Regular updates to monitoring data and population projections are necessary for the Multi-Species Action Plan to Conserve African-Eurasian Vultures (MsAP; Botha et al., 2017) in order to assess their progress.

It is a well-known fact that all vulture species have experienced a significant reduction over the past few decades in Africa (Balodi et al., 2018). The main causes of the vulture population decline have been identified as poisoning, habitat destruction, and traditional uses (Ogada et al., 2011). However, there is little information on their population status and geographic range available globally. Furthermore, the effects of vulture decline, whose function in our environment is that of a natural scavenger has not been yet determined. Regular updates to monitored data and population estimations are necessary for conservation efforts to be effective (Ogada et al., 2011). In this background, Nature Tanzania, with the financial support of the Darwin Initiative through BirdLife International, conducted a two-season quick survey of vulture population in the Makao WMA, Mwiba Ranch, and other known potential sites for vultures within villages forming Makao WMA. The survey aims to enhance vulture conservation that is informed by scientific information on the population size and distribution in the Area and will contribute to developing a vulture conservation action plan in Tanzania. It also aims at establishing baseline data on the current population status through population counts and distribution patterns.

METHODOLOGY

Study Area

The study was conducted at Makao Wildlife Management Area (WMA) and Mwiba Ranch Area, covering a total of 840,116 hectares. Makao WMA is a protected area located in north-central Tanzania, in Meatu District, Simiyu Region. Makao WMA serves as an important ecological linkage between Maswa Game Reserve, Ngorongoro Conservation Area, and Serengeti National Park. Makao WMA is rich in wildlife species, including lions, leopards, roan antelope, buffalo, and lesser and greater kudu, which are mostly trophy enemies. Others are hartebeest, klipspringer, zebra, warthog, and wildebeest. Groups of elephants are also found in the area. Rare species like wild dogs are also sighted in some areas. The WMA is the southernmost end of the famous wildebeest migration, and migrating ungulates only visit this area if other areas in the Serengeti have no grass or water. The area is used as an emergency zone by these migrating ungulates, especially during the months of December through May. The place is also a home for globally threatened species of vultures, restricted-range species of birds, and many other species of birds. Cultivation (cotton, maize, sorghum, and sunflower) and livestock-keeping (large heads of cattle) are the major economic activities in Makao WMA member villages.

Data collection using road counts

Data were collected within two different seasons, during and after the wildebeest migration season, by using the road transects survey method. At first, we conducted a reconnaissance survey on vulture awareness in the communities forming Makao WMA, as well as with Village Game Scouts (VGS) working within the WMA. For villagers, we focused on herders, who spend most of their time in the field (grazing areas) with the possibility of encountering vultures. We gathered data on vultures, including their knowledge, sightings, locations within Makao WMA, and vulture breeding grounds. We named different sites where herders and VGS spotted vultures using the local names. We designed our transects based on the areas highlighted in the reconnaissance surveys. We developed nine transects, naming them Transect 1 (42 km), Transect 2 (28.4 km), Transect 3 (7.8 km), Transect 4 (14.1 km), Transect 5 (10 km), Transect 6 (13.3 km), Transect 7 (46.1 km), Transect 8 (20 km), and Transect 9 (26.9 km), and developed them in areas accessible by roads, as the plan was for a road transect survey. Transects 7 and 8 are located within Makao WMA, near the Ngorongoro Conservation Area and Maswa Game Reserve, respectively. The nine transects formed covered a total distance of 208.6 km, with variations in distances between transects depending on the area's infrastructure and accessibility. The protocol of Buckland et al., (1993) was adopted to meet the key assumptions of distance sampling, namely (1) sufficient length of the survey to detect an adequate number of vultures, we surveyed 208.6 km for our study, meeting the recommended minimum coverage of 200 km (2) accurate distance measurements from the transects, and (3) individuals close to transects are always detected, we were five people, each person observing his side (left, right, front, and behind) with a pair of binoculars to observe vultures in either sides, and one person taking note. In this research, it is assumed that vultures fly randomly over suitable habitats, which meets the criteria for distance sampling using vehicle transects. So, all individuals counted with no truncation distance for the vehicle transects. We covered one transect per day with an average vehicle speed of 15 km/hr.

Data analysis

We cleaned the obtained data and entered it into Microsoft Excel for analysis. The diversity was calculated used Shannon diversity index formula;

$H=-\sum[(p\text{i})\times\log(p\text{i})]$ where;

H - Shannon diversity index;

pi - proportion of individuals of i-th species in a whole community;

$\sum$ - sum symbol; and

log - usually the natural logarithm, but the base of the logarithm is arbitrary (10 and 2 based logarithms are also used)

RESULTS

The vulture species found in Makao WMA

Generally, from the two surveys, only four different species of vultures named Lappet-faced Vulture, Ruppell's Vulture, White-backed Vulture, and Palm-nut Vulture were observed. The observed species performed different activities, such as flying, flying over, perching, and feeding. The findings in Table 1 show that vultures were seen in only two transects (transect 7 and transect 8). All four species were seen in transect 7, while the Ruppell's vulture and Palm-nut Vulture were seen in transect 8. The most seen vulture was the White-backed Vulture (150), followed by the Ruppell's Vulture (37) and the Lappet-faced vulture (22). The least seen was Palm-nut Vulture (4). Results in Table 2 show that vultures were observed in transect 3 and transect 8. One Ruppell's Vulture was seen in transect 3, and two Lappet-faced Vultures were observed in transect 8.

Table 1: Shows vulture species, frequency of observation and their total count along the transects during wildebeest migration season.

Species name		Frequency and counts (in brackets) recorded along Transects (T1-T9) placed at different distance intervals								
Common name	Scientific name	T1	T2	T3	T4	T5	T6	T7	T8	T9
		42 km	28.4 km	7.8 km	14.1 km	10 km	13.3 km	46.1 km	20 km	26.9 km
Lappet-faced Vulture	*Torgos tracheliotos*	-	-	-	-	-	-	4 (22)	-	-
Ruppell's Vulture	*Gyps rueppelli*	-	-	-	-	-	-	4 (35)	1 (2)	-
White-backed Vulture	*Gyps africanus*	-	-	-	-	-	-	5 (150)	-	-
Palm-nut Vulture	*Gypohierax angolensis*	-	-	-	-	-	-	2 (3)	1 (1)	-

Table 2: Shows vulture species, frequency of observation and their total count along the transects after wildebeest migration season.

Species name		Frequency and counts (in brackets) recorded along Transects (T1-T9) placed at different distance intervals								
Common name	Scientific name	T1	T2	T3	T4	T5	T6	T7	T8	T9
		42 km	28.4 km	7.8 km	14.1 km	10 km	13.3 km	46.1 km	20 km	26.9 km
Lappet-faced Vulture	*Torgos tracheliotos*	-	-	-	-	-	-	-	1 (2)	-
Ruppell's Vulture	*Gyps rueppelli*	-	-	1(1)	-	-	-	-	-	-

The species seasonal diversity of vultures in Makao WMA

Referring to the survey result from Table 1, it shows that during wildebeest migration vultures were recorded in only two transects (7 and 8). The findings in Table 3 show that Transect 7 was more diverse (H = 0.84) compared to Transect 8 (H = 0.07). For non-wildebeest migration season, vultures were also recorded in two transects 3 and 8 (Table 2), with their diversity H = 0.37 and H = 0.27 respectively (Table 4).

Table 3: Shows proportional comparison for vultures between transects during wildebeest migration season

Common name	Scientific name	T1	T2	T3	T4	T5	T6	T7	T8	T9
		42 km	28.4 km	7.8 km	14.1 km	10 km	13.3 km	46.1 km	20 km	26.9 km
Lappet-faced Vulture	*Torgos tracheliotos*	-	-	-	-	-	-	4 (22)	-	-
Ruppell's Vulture	*Gyps rueppelli*	-	-	-	-	-	-	4 (35)	1 (2)	-
White-backed Vulture	*Gyps africanus*	-	-	-	-	-	-	5 (150)	-	-
Palm-nut Vulture	*Gypohierax angolensis*	-	-	-	-	-	-	2 (3)	1 (1)	-
Frequency proportion		0	0	0	0	0	0	4	1	0
Proportion of counts		0	0	0	0	0	0	53	1	0

Table 4: Shows Vulture species and their diversity per transect during wildebeest migration season

Transect	Common name	Scientific name	Number	pi	lnpi	pi*lnpi	H
7	Lappet-faced Vulture	*Torgos tracheliotos*	22	0.10	-2.27	-0.23	0.84
	Ruppell's Vulture	*Gyps rueppelli*	35	0.16	-1.81	-0.30	
	White-backed Vulture	*Gyps africanus*	150	0.70	-0.35	-0.25	
	Palm-nut Vulture	*Gypohierax angolensis*	3	0.01	-4.26	-0.06	
8	Lappet-faced Vulture	*Torgos tracheliotos*	0	0.00	0.00	0.00	0.07
	Ruppell's Vulture	*Gyps rueppelli*	2	0.01	-4.67	-0.04	
	White-backed Vulture	*Gyps africanus*	0	0.00	0.00	0.00	
	Palm-nut Vulture	*Gypohierax angolensis*	1	0.00	-5.36	-0.03	

Table 5: shows proportional comparison for vultures between transects during non-wildebeest migration season

Common name	Scientific name	T1	T2	T3	T4	T5	T6	T7	T8	T9
		42 km	28.4 km	7.8 km	14.1 km	10 km	13.3 km	46.1 km	20 km	26.9 km
Lappet-faced Vulture	*Torgos tracheliotos*	-	-	-	-	-	-	-	1 (2)	-
Ruppell's Vulture	*Gyps rueppelli*	-	-	1 (1)	-	-	-	-	-	-
Frequency proportion		0	0	1	0	0	0	4	1	0
Proportion of counts		0	0	1	0	0	0	53	1	0

Table 6: Shows Vulture species and their diversity per transect during non-wildebeest migration season

Transect	Common name	Scientific name	Number	pi	lnpi	pi*lnpi	H
3	Lappet-faced Vulture	*Torgos tracheliotos*	0	0.00	0.00	0.00	0.37
	Ruppell's Vulture	*Gyps rueppelli*	1	0.333	-1.10	-0.37	
8	Lappet-faced Vulture	*Torgos tracheliotos*	2	0.67	-0.41	-0.27	0.27
	Ruppell's Vulture	*Gyps rueppelli*	0	0.00	0.00	0.00	

DISCUSSION

The findings in Table 1 show that vultures were seen in only two transects (transect 7 and transect 8). All four species were seen in transect 7, while the Ruppell's vulture and Palm-nut Vulture were seen in transect 8. This could be due to the fact that the two transects enclosed the Ngorongoro Conservation Area and accommodated a large population of wildebeests, who are normally followed by carnivores and vultures. Also, the results show that the most seen vulture was the White-backed Vulture, followed by the Ruppell's Vulture and the Lappet-faced vulture. The least seen was Palm-nut Vulture. The counts and frequency of vultures was high during the wildebeest migration season than that of non-wildebeest migration season. The population of wildebeest at Makao WMA during migration season attracts predators such as lions, leopards, and hyenas. This also attracts vultures, who will feed on the remains after predators kill them, and other mortality factors for wildebeests, such as diseases and starvation (Virani et al., 2012). Studies of vultures in Mara-Serengeti indicate that abundance is highest in areas near migrating ungulates and have concluded that the vultures follow the migratory herds (Kendall et al., 2012).

Referring to the survey result from Table 1, it shows that vultures were recorded in only two transects (7 and 8). The findings in Table 4 show that Transect 7 was more diverse (H = 0.84) compared to Transect 8 (0.07). The reason behind this could be the proximity of the transect to the Ngorongoro Conservation Area, which has a diverse population of large mammals throughout the year. As vultures, most of the time they prefer areas with animals compared to those without animals (Kruuk, 1967; Kendall, 2013). Also, the high population of wildebeest in Transect 7 may attract the presence of vultures around the area (Kendall et al., 2012). Regarding transect 7, as we observe sometimes the three vulture species to the same carcass, the processes that allow Lappet-faced (Torgos tracheliotos), White-backed (Gyps africanus), and Ruppell's vultures (Gyps rueppellii) to cohabit are unknown due to their dependence on a shared resource. Given the similarities in their feeding and social behaviours, the coexistence of the two Gpys species in particular is challenging to understand (Jackson et al., 2008; Virani et al., 2010). On the other hand, for non-wildebeest migration season, vultures were also recorded in two transects 3 and 8 (Table 2), with their diversity H = 0.37 and H = 0.27 respectively (Table 4). The numbers and diversity of vultures after wildebeest migration look smaller compared to those during wildebeest migration, this is similar to the findings of Kendall et al., 2012.

CONCLUSION

In conclusion, we observed four species of vultures: Lappet-faced Vulture, Ruppell's Vulture, White-backed Vulture, and Palm-nut Vulture. The findings indicate that the availability of wildebeest significantly influences the presence of vultures in the study area. The number and diversity of vultures appear to be higher during the wildebeest migration season compared to the non-wildebeest migration season. Monitoring of the population is necessary to determine whether the apparent fall of scavenging birds in East Africa is local or regional and to clarify the causes of population declines. Conducting such surveys across multiple seasons is crucial to gather more data for comparison analysis, as the observed differences may be due to factors other than wildebeest movement. The study's limitations include insufficient funds to conduct surveys in multiple seasons, unfavorable road conditions during rainy seasons, and a lack of roads in certain parts of the WMA, which resulted in our inability to cover a significant area.

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NATURE AND EXTENT OF HUMAN-HIPPOPOTAMUS (*HIPPOPOTAMUS AMPHIBIUS*) CONFLICT IN BUSEGA DISTRICT, NORTH- WESTERN TANZANIA

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ABSTRACT

Hippopotamuses (Hippopotamus amphibius) are the third largest terrestrial mammal that highly threatened by widespread poaching, habitat loss, and fragmentation. Human-Hippopotamus Conflict (HHC) is a complex interaction between hippopotamus and humans, which often results in detrimental impacts to both species. A well understanding of HHC improves effective mitigation strategies and promotes people's well-being. The study assessed the extent and type of damage caused by hippopotamuss in four HHC hotspots wards in the Busega district and explores possible conflict mitigation solutions to enable conciliatory cohabitation between hippopotamuses and humans. A total of 344 people were interviewed in 12 villages using semi-structured questionnaires. About 86.6% of the respondents recorded that the hippopotamus was present in the study area and about 55.8% had encountered a hippopotamus attack. The results indicated that the major conflict caused by the hippopotamus was crop raiding (78.78% of respondents), as well as human death and injury. The study found that maize (Zea mays), sweet potatoes (Ipomoea batatas), cassava (Manihot esculenta), and tomatoes (Solanum lycopersicum) were mostly grown and the most raided crops at their early and mid-stage of development. Preventive measures currently undertaken involve traditional scare-away techniques such as making noise by shouting, guarding farms, beating drums and tins, lighting fires, and fences, using torches, and throwing stones. The HHC victims have suggested mitigation measures like culling (66%), simply driving away (8%), building ranger posts close to water bodies (7%), hippopotamus translocation (7%), government intervention (5%), education on HHC mitigation (3%), fencing water bodies (2%) and stop cultivation near water bodies (2%). This study highlights the necessity to implement mitigation measures to resolve the conflict between hippopotamuses and the local community in the Busega district and to promote the conservation of this species in the study area.

Keywords: conflict, conservation, district, hippopotamus, measures

INTRODUCTION

Tanzania harbors the largest freshwater lakes in Africa and is blessed to have many rivers, wetlands, lakes, and groundwater resources. These endowed—water resources are home to an extraordinary diversity and density of wildlife including the common hippopotamuses *(Hippopotamus amphibius)* (Kendall, 2011). The common hippopotamuses or Hippos are the member of the family Hippopotamidae and the third largest and heaviest land mammal after elephants (*Loxodonta africana*) and white rhinos (*Ceratotherium simum*) (Laursen & Bekoff, 1978; Kena & Erena, 2022). Moreover, hippos are listed as "vulnerable" on the IUCN Red List of Threatened Species, with a population of 115,000–130,000 individuals (Kena & Erena, 2022). They are non-ruminant artiodactyls with a distinctive way of living among big mammals, having stomachs which are built to get the most nutrients out of the lower-energy meals they eat (Fogler et al., 2000; Kena & Erena, 2022). Hippos are social animals comprised of individuals of mixed ages and sexes depending on location and season. The size of hippo aggregations may range from a few individuals to as many as 100 or 150 individuals (Kena & Erena, 2022). Historically, hippos were found to occur throughout the sub-Saharan Africa, but their populations are greatly declining while others have disappeared from many countries (Kena & Erena, 2022). They predominantly inhabit lakes, rivers, and marshy ponds of many sub-Saharan countries (Kena & Erena, 2022). Hippos differ from other mega-herbivores in that it requires both a daily living space in the water and an open grazing range on land at night and this requirement affects the way that hippos use resources and survive in a human-dominated landscape and continuous land-use changes. Therefore, the spatial distribution of an organism is mainly influenced by the appropriateness of the environment for its survival, growth, and reproduction (Adounkè et al., 2021).

However, the global growth of the human population and the demand for more land, water, and natural resources are escalating conflicts between people and wildlife (Kang et al., 2011). According to kanga et al. (2011) Human-wildlife conflicts (HWC) result from negative interactions, causing economic losses in agriculture, human casualties, livestock depredation, and retaliatory killings of wildlife. This increasing trend, particularly with Hippos, is noticeable in Tanzania. Human-Hippo Conflicts (HHC) occur when hippo populations endanger human lives or livelihoods, leading to the animals being persecuted in retaliation. These conflicts are significantly rising in Tanzania due to the loss of suitable habitats for hippos, driven by human population growth and unsustainable land use conversion to agriculture in wetland areas where hippos live(van Houdt and Traill 2022).The study by Matema et al. (2022) reported that Hippo's survival requires extensive terrestrial wetland grazing areas which draw them into conflict with communities that rely on ecosystem services provided by the same wetland. In most cases, HHC has negatively affected local people's livelihoods as hippopotamus tend to feed on crops along their ranges hence leading to food crisis (Houdt and Traill 2022; Lumbonyi et al. 2023)Nigeria. The study had the following specific goals; describe the direct effects of Human Hippopotamus Conflict (HHC. In Tanzania for example water bodies located in urban and peri urban areas are among the vulnerable locations to HHC because they provide suitable environment for hippopotamus. Though most communities living adjacent to these water bodies in Tanzania have been adversely impacted for a long time by HHC, but this conflict in those areas have rarely been studied particularly in Busega District. In this study, we hypothesized that most HHC in Busega would occur more frequently and intensively in villages closer to the lake shore and hippopotamus access points (defined as places where hippopotamuses consistently enter and leave the lakes, leading to trails). This was because the previous study by Kendall (2011), reported that most HHC around Ruaha National Park occurred more intensively in villages, where farming activities were carried out closer to the river and hippopotamus access point. Therefore, the current study assessed the extent and type of damage caused by hippopotamus in four HHC hotspots wards in Busega district and explores possible conflict mitigation solutions so as to enable conciliatory cohabitation between hippopotamus and human in the area. We hypothesized that most HHC in Busega would occur more frequently and intensively in farms which are closer to the lake shore and hippopotamus access points (Kendall, 2011; Mmbaga, 2022).

MATERIALS AND METHODS

Study area

The study was conducted in Busega District at Simiyu Region (Figure 1). The Busega district is one of five districts in Simiyu Region of Tanzania, namely, Meatu, Itilima, Bariadi, Maswa and Busega. Busega district is located on the northwestern part of Simiyu Region and shares borders with Magu districts in west, Bariadi districts in south, The southeastern part is covered by the Serengeti game reserve and Bunda district (Vats and Thomas, 2015). According to Vats and Thomas, (2015), in north side it bordered with Lake Victoria. As a result, many community members utilize both aquatic and terrestrial organisms as a source of medicine. Busega district is located between latitude 2^0 10'and 2^0 50'South and between longitude 33^0 and 34^0 East (Vats and Thomas, 2015). The district headquarter is in Nyashimo town. The district is divided into thirteen (13) wards and fifty four (54) villages as per Tanzania Population and Housing Census 2012. Busega district is Tropical in nature with sun overhead of equator on March and October (Vats and Thomas, 2015). Temperature is tropical and range between 25°C and 30°C with average annual temperature of 27°C. There are two wet seasons, the long rains from mid-March to early June, during which the precipitation is between 700 mm to 1000 mm and averages 800 mm per annum and short rains from October to December, during which the rainfall is between 400 mm to 500 mm (Vats and Thomas, 2015).

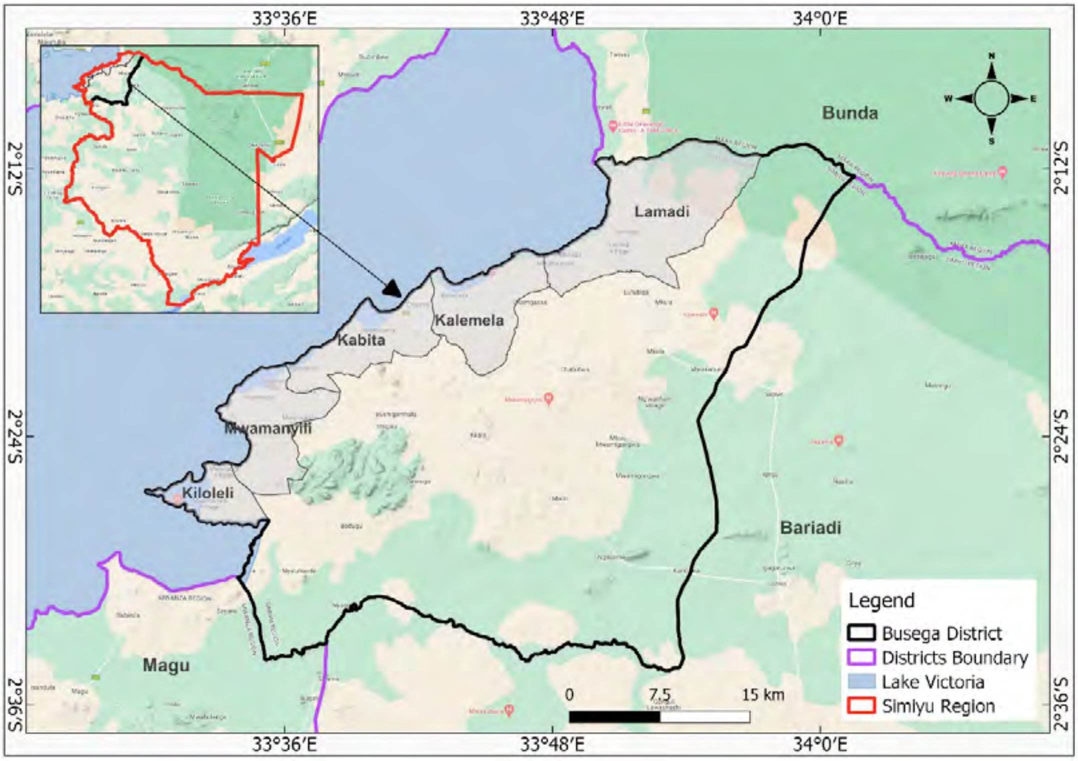

Figure 1: Map of the study area showing the wards with human hippopotamus conflict in Busega district, Simiyu region

Data collection

The study adopted a mixed research method in collecting the data. HHC data in Busega District were collected from 11-24 Nov. 2022 using Household Questionnaires (HQ), and direct observation (DO) methods from four wards namely Kabita, Kalemela, Kiloleli and Mwamanyili that were selected based on their reports of having high levels of HHC and their proximity to Lake Victoria, which would predispose the ward to higher conflict with the hippopotamuses. From each ward, at least three villages that had high, medium and low incidence of HHC were selected for data collection. All information regarding the wards and villages with HHC that were selected in this study was obtained from the District Game Officer (GDO), District Executive Officer (DED) and Regional Game Officer (RGO). However, before visiting villages, the District Game Officer (DGO) informed the village leaders on the visitation of the TAWIRI researchers to their village. In each village with the assistance of the village leaders, at least a total 30 respondents aged 19 years and above representing 30 village households based on the village register book, who had lived in the area for at least five years or more including both victims and non-victims of HHC were randomly selected for HQ interview. Additionally, before administering household questionnaires to respondents, the researchers were introduced by the respective village leaders and were asked on their consent to be interviewed. During the interviews, household questionnaires (HQ) were used. All household interviews and recording of household questionnaire (HQ) responses employed the Kobo Collect App installed on tablets and phones.

In addition, the direct observation method was used to assess the conflict areas and determine the economic losses incurred by the participants in the period under review.

Data analysis

The Statistical Package for Social Science (SPSS, version 16.0) software and Microsoft Excel Office 2019 were used to analyze the data. Descriptive statistics were used to summarize the data into tables, percentages, and charts. The χ^2 test was used to compare respondents' benefits and attitudes toward hippos' presence in their area. All tests reported at level of $p \leq 0.05$ were considered statistically significant.

RESULTS

Demographic characteristics of the respondents

Our results revealed that the majority of respondents N = 344 were represented more by men (65.3%) than women (34.7%) and were above 20 years (99.7%) old. This was because most men were the head of the household and were more knowledgeable on matters related to HHC than women were in their areas. The majority of them have attained primary school education (71.4%) compared to those who had never attended formal school (17.8%). While few numbers of respondents attained secondary (9.1%) and University or College (1.7%). Among the respondents majority (86.6%, N = 344) admitted that hippos were found in the areas where they live and carry out their daily activities. While the remaining few others (12%, 1.4%) respectively admitted that hippos were either not found or did not know if they were found in the areas where they live and carry out their daily activities. However, (55.8%) of the respondents have encountered a hippopotamus attack in their area.

Direct effects of human-hippo conflict on livelihoods

Moreover, majority of the respondents (78.78%), reported that crop raiding was the major HHC type in Busega followed by human injury, human death and threat to human life. In addition the majority of respondents were cultivating their crops within a distance of 0m-500m from the lake shore and they experienced higher incidences of hippopotamus crop damage compared to those whose farms were beyond 3km. Also, most of the respondents in Busega district mentioned that high HHC incidences occurred almost throughout the year but that of the crop damage mostly of maize (*Zea mays*), sweet potatoes (*Ipomoea batatas*), cassava (*Manihot esculenta*) and tomatoes (*Solanum lycopersicum*), cotton (*Gossypium herbaceum*), rice (*Oryza sativa*) and beans (*Phaseolus vulgaris* L.) picked during the young and intermediate growth stage of most crops which is in between November and February of each year (Figure 2). It was noted that about 90.6% of the respondents reported there is increased of HHC as the result of the increase in hippopotamus population in their area.

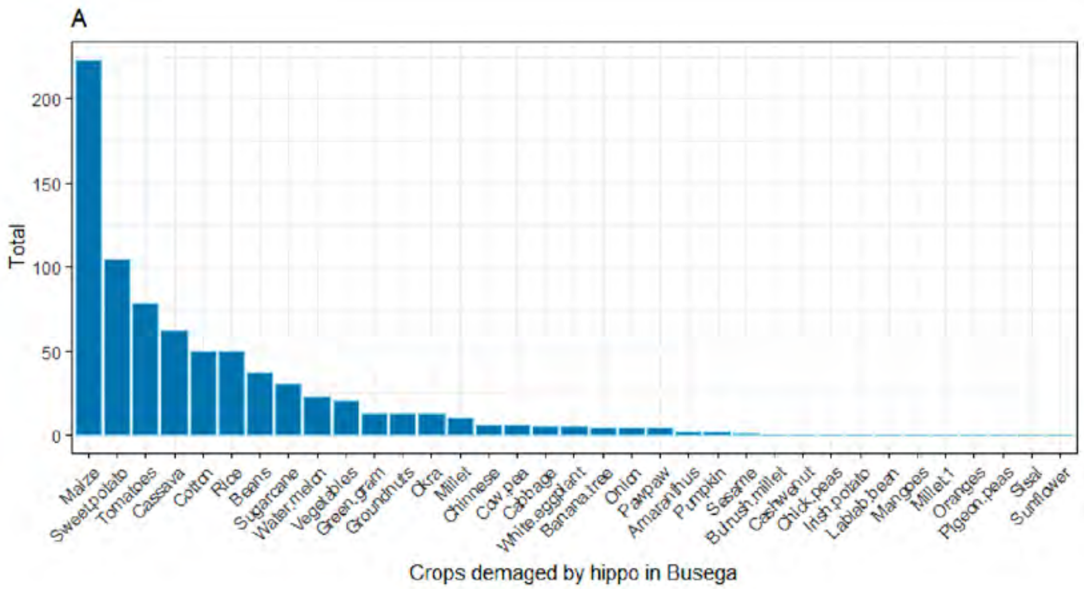

Figure 2: Crops damaged by hippopotamus in Busega districts (N=268).

Also, the majority of respondents (n = 291, 84.6%) did not benefit financially from Hipposhippo's presence in their area compared to those who have benefited (n = 4, 1.2%), and those who didn't know (n = 49, 14.2%) and their differences were statistically significant (χ^2 = 33.7, df = 6, P < 0.001). In addition, generally, majority of the respondents reported about five major mitigation techniques that were commonly used in their areas including guarding the farms in wooden huts (37.7%), using torches (26.4%), making noise (beating drums, tins, etc.) (15.3%), fencing farms with thorns, pieces of cloths etc. (12.8%) and lighting fires (3.1%; Figure 3).

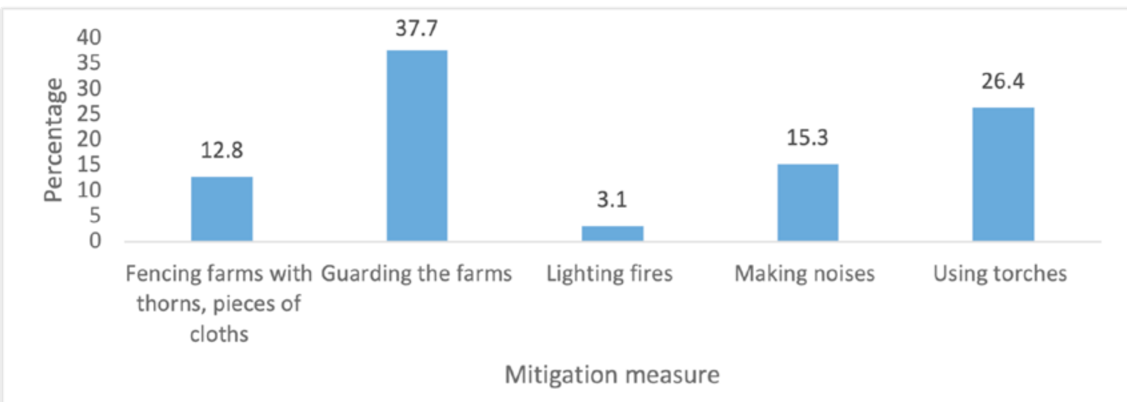

Figure 3: Mitigation measures currently and commonly used by people in Busega District

The HHC victims suggested mitigation measures to be used like culling (66%), simply drive away (8%), building ranger posts close to water bodies (7%), hippopotamus translocation (7%), government intervention (5%), education on HHC mitigation (3%), fencing water bodies (2%) and stop cultivation near water bodies (2%; Figure 4). Moreover, in Busega district the implementation of land use plan was not in place as reported by most respondents (n = 249, 72.17%). Based on the fact that, Environmental Management Act of Tanzania mainland, No. 20 of 2004 section 57(1) prohibit human activities within 60m of a water dam, reservoir or water source, most respondents again reported that the regulation was not followed in Busega (n = 191, 55.36%).

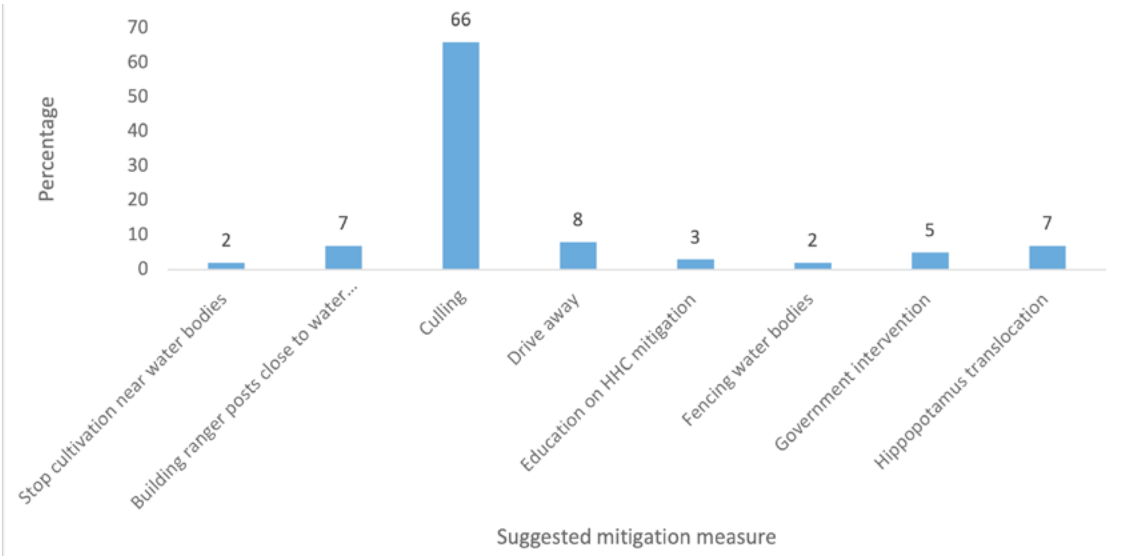

Figure 4: Suggested effective mitigation measures by people of Busega District

DISCUSSION

Our finding revealed that HHC exists in the Busega District as the majority of the respondents admitted that they had encountered hippopotamus attacks and also hippos were present in their area. Therefore, supporting finding that hippopotamuses are among Africa's most destructive crop raiders (Lumbonyi et al., 2023). This could be attributed to the depletion of natural forage by livestock which would have driven hippos to raid crops and then increased their conflict with people (Teshome & Erena, 2022). Again, the other reason could be due to increased anthropogenic disturbances which have led to hippos' habitat constriction and eventually severe competition for natural resources between them and the local communities (Yalden and Largen, 1992; Ertiban, 2016). Our findings also support those of the previous study by Kanga et al., (2012) who found that the probable proximate causes of HHC are linked to increasing human population and the associated increase in demand for agricultural and settlement space, especially in areas close to water, and the fact that hippos, humans and their livestock compete for resources along wetland margins. In addition, drought and competition with livestock might have forced hippos to forage further from their daily living space, increasing their probability of contact with humans (Kanga et al., 2012). The same scenario was observed in Busega District because currently when hippos emerge from the lake the first vegetation they come across is the crop farm with either maize, rice, or other crops. Therefore, because hippos are left without alternative wild forage, they graze on those crops causing hippo-human conflict (HHC). In addition, HHC was reported to increase in the area as a result of the increase in the hippopotamus population.

Moreover, the finding revealed that crop raiding mostly of maize, sweet potatoes, tomatoes, cassava, cotton, rice, and beans was the most commonly reported HHC in Busega District compared to others including human injury, human death, and threat to human life. This pattern of HHC is similar to that found in the study by Ertiban, (2016) who reported that the hippopotamus's crop raids are unpredictable and can cause more damage per raid. The reason might be that majority of respondents in Busega District were cultivating their crops within a short distance of 0m-500m from the lake shore (Figure 5) as they were found to experience higher incidences of hippopotamus crop damage compared to those whose farms were beyond 3km. Our finding also are consistence with those of the previous study which found that crop raids by hippos are more frequent and common on the farms within 0-100 metres from the riverbanks and the frequency of raiding as well as the rate of damage decreases with the increased distance from the river or lake (Jamusana, 1994). Again, the relatively high human population growth rates and the rapid conversion of hippos' natural habitats, has brought people and hippos into increasing proximity and competition, particularly in areas where extensive farming has taken place (Post, 2017). Since, according to Post (2017) hippos have expanded their diets with agricultural crops that are commonly grown along water bodies as they are pushed by shrinking grazing grounds.

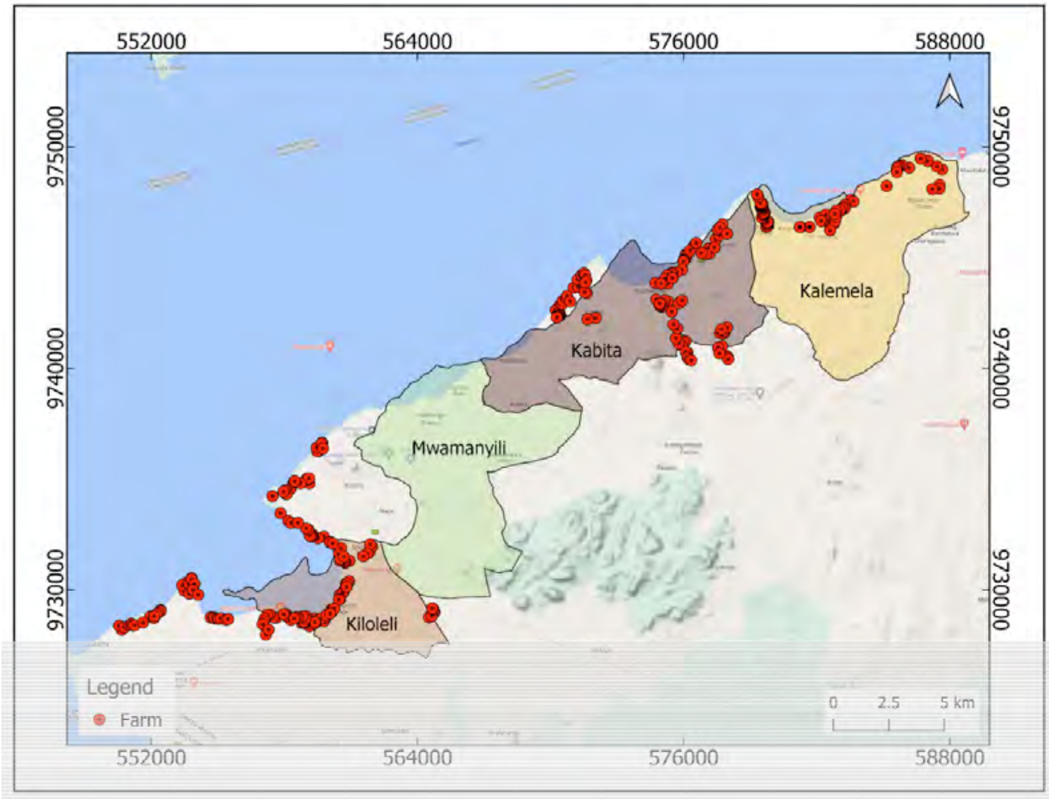

Figure 5: Map showing the location of farms in the study area

Our finding is also consistent with that of the study by Teshome & Erena, (2022) who reported that Hippos commonly destroy crops cultivated close to wetlands and pose physical threats to the local communities. Moreover, the study by van Houdt and Trail (2022) revealed that most of the HHC in Africa occur in proximity to water sources, with most conflict taking place within 1,000 meters away from water. Similarly, the study by Kendall (2011), reported that most HHC around Ruaha National Park occurred more intensively in villages, where farming activities were carried out was closer to the river and closer to hippopotamus access points.

Additionally, although HHC incidences in Busega District were reported to occur throughout the year but they picked between November and February each year especially when most crops (i.e. maize, sweet potatoes, tomatoes, cassava, cotton, rice, and beans) were at their young and intermediate growth stage. This finding is consistent with those of the previous study by van Houdt and Traill, (2022) who reported that crop raiding by hippos may be seasonal too, affected by rainfall and crop growth stages. Again, the study by van Houdt and Traill, (2022) found that food and cash crops damaged by hippos were maize, rice, pumpkins, groundnuts, sweet potatoes, cassava, sugarcane, sorghum, cabbage, and cowpeas which when averaged per farm was greater than the monthly household income. The costs of crop damage (by hippos) were greater than the income generated by the species (through tourism and hunting) in the area, while the opposite was true of elephants (van Houdt and Traill, 2022). This might be why, most of the respondents expressed negative attitudes towards hippos' conservation as they reported that they did not benefit from hippos's presence in their area. This finding concurs with that of the study by Post, (2017) who found that evidently, many people had low tolerance levels and a hostile attitude towards hippos, which they felt were causing damage to their properties and life support systems, particularly towards the authorities responsible for wildlife conservation since these had failed to take care of their animals.

Furthermore, our findings revealed that people in Busega applied different mitigation measures to reduce HHC in their area. These include mostly guarding their farms, using torches, making noise (beating drums, tins, etc.), fencing farms with thorns, pieces of cloth, etc., and lighting fires. This finding is similar to that of the study by Ertiban (2016) who reported that farmers who live in and around Lake Victoria used fencing materials like cedar poles and barbed wire and digging of trenches to minimize crop damage by hippopotamus in their area. Also, the finding is consistent with previous findings by van Houdt and Trail, (2022) who reported that most of the respondents suggested guarding of sugarcane plantations was mostly used and more successful than other methods, followed by fencing, trenching, and burning fire at night in the study area. Additionally, the majority of respondents in Busega District suggested that the proper mitigation measures they thought could reduce HHC in their area include firstly hippos harvesting/culling, followed by simply driving them away, building ranger posts close to the lake, hippopotamus translocation, government intervention, education on HHC mitigation measures, fencing water bodies and stop cultivation near water bodies.

CONCLUSION AND RECOMMENDATIONS

The study concludes that HHC more specifically on crop raiding exists and is a great challenge to the communities adjacent to Lake Victoria especially those of the Busega District. Hippos raided both food and cash crops as majority of the crops farms were within a short distance from the lake shore (i.e. 0m-500m). As the result, most of the respondents expressed negative attitudes towards hippos' conservation as they did not benefit financially from hippos presence in their area. Therefore, there is a need to empower local community by promoting ecotourism activities in Busega District because they will benefit financially from the species presence in their area. These results strongly suggest that the increasing HHC are a result of increasing human encroachment into areas that were previously used by hippos for forage and retreat during daytime hours. Therefore, though different measures have been used and suggested by the local community to reduce HHC in their area, this study recommends firstly that people should adhere to the current existing environmental conservation laws i.e. leaving a buffer zone of 60m from the water body line. Secondly, initiation of proper land use planning including zoning the lake and its shoreline into (i) no use (ii) medium, and (iii) high use to locations of hippo schools and diversifying their crops to reduce the number of elephant raids and enable farmers to obtain increased incomes and improve food security. Thirdly, public education and awareness campaigns to communities on hippos' ecology and behavior as well as the proper HHC mitigation measures. Fourthly, growing live fences around farms, for example, using sisal (*Agave sisalana*) that are easier to grow and are tall enough to prevent hippos from crossing over into farms. Fifthly, employing an integrated strategy which includes continuing to pay consolation to those affected by HHC while at the same time initiating and implementing a large drip irrigation scheme in Busega District to enable people to cultivate their crops at least 1Km far away from the lake shore with all other measures reported above.

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NEW RECORD ON CAPTURE AND CONSUMPTION OF TWO JUVENILE RED-LEGGED SUN SQUIRRELS (SPECIES) BY A FEMALE CHIMPANZEE IN MAHALE MOUNTAINS NATIONAL PARK, TANZANIA

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ABSTRACT

In many chimpanzee study sites, females and immature chimpanzee individuals have been less observed in hunting than male chimpanzees. However, solitary and silent hunting attempts by such individuals may have been missed. Chimpanzees hunt, kill and consume a variety of prey though there are difference in the frequency of hunting between savanna and forest sites. They hunt primate species, ungulates, rodents, birds, lizards and frogs. Nevertheless, they show a clear focus on mammalian prey. Hunting techniques employed in hunting may vary between chimpanzee populations and depending on the type or age of prey. While there are records of tool aided squirrel predation by the Mahale chimpanzees, there have been no record of chimpanzees to hunt and capture squirrel bare-handed before. The use of tools in squirrel hunting by chimpanzees has been argued as material to rouse the hiding squirrel from a tree hole and to reduce the risk of being bitten by the squirrel's powerful incisor teeth during "bare-handed" exploration in the hole. Unlike in the previous records where chimpanzees used tools to hunt and kill squirrel, here we report, a solitary female chimpanzee who conducted a bare-handed explorative search in the hole of a tree, and succeeded to capture two juvenile squirrels hiding in the hole and consumed almost all both of them, alone. This observation suggests that hunting techniques in chimpanzees can be diverse than reported to date. Further, we explore, compare and discuss the behavior exhibited.

Keywords: bare-hand exploration, chimpanzees, predation, prey, prey-capture styles

INTRODUCTION

Chimpanzees (*Pan troglodytes*) are known to hunt, kill and consume a variety of prey (Nishida, Uehara and Nyundo 1979, Newton-Fisher 2015, Goodall 1968, Teleki 1973, Uehara 1997, Mitani and Watts 1999a). They hunt primate species, ungulates, rodents, birds, lizards and frogs; however, they show a clear focus on mammalian prey (Goodall 1968, Newton-Fisher 2015). The hunting frequency, choice of the prey species, and the techniques employed in hunting vary between chimpanzee populations (Hobaiter et al. 2017, Nishida 1992). Prey are typically small, up to a maximum of around 20 kg (Kingdon 1997), but often much smaller (Goodall 1986). Red colobus monkeys (*Piliocolobus* spp.) have appeared as the most preferred prey species in all the sites where they live sympatric to chimpanzees (Ramirez-Amaya et al. 2015, Uehara 1997, Mitani and Watts 1999b).

Chimpanzees are opportunistic hunters (Goodall 1986) but sometimes they can actively search for prey nestlings or eggs in a tree hollow (Wrangham 1975). During a hunt, chimpanzees chase, seize, and kill the prey either by a bite, disembowelment or by tearing it apart (Goodall 1986). After successful hunting, meat-eating behavior in chimpanzees is widely observed. In Tanzania, chimpanzees of Mahale Mountains National Park (MMNP) have been continuously studied since 1965 providing valuable information on their dietary ecology and feeding behaviour (Nakamura et al. 2015, Nishida 1990, Nishida 2012). Despite many observations of hunting and meat consumption by chimpanzees, only 11 cases (Table 1) of chimpanzee hunting squirrels at MMNP have been documented (Hosaka et al., 2020).

Table 1. The documented squirrel hunt by chimpanzees at MMNP

Species	Hunt	Kill	Eat	Carry	Toy	Reference
Squirrel	11	8	5	2	1	Hosaka et al., 2020

In 1993, Huffman and Kalunde reported the first tool aided squirrel predation, which was also the second reported case of successful predation on squirrels at MMNP since research began in 1965 (Nishida et al. 1979, Nishida and Uehara 1983, Takahata, Hasegawa and Nishida 1984). The reported hunting case was tool-assisted predation, which led to the immediate capture of a red-legged sun squirrel-*Heliosciurus rufobrachium* (Huffman and Kalunde 1993). Huffman and Kalunde (1993) observed the chimpanzee using a branch of a tree to rouse the hiding squirrel from a tree hole and suggested it was done to reduce the risk of being bitten by the squirrel's powerful incisor teeth during "bare-handed" exploration in the hole. The hunter then shared the meat, with another young orphan female in the secrecy of a temporary day bed.

Occasional solitary hunting of squirrels and subsequent consumption has been observed in MMNP chimpanzees recently. Unlike the previous observation reported by Huffman and Kalunde (1993) where chimpanzees used tools to hunt and kill the prey, in the current study, a solitary female chimpanzee was observed conducting a bare-handed explorative search in the hole of a tree, where she succeeded to capture two juvenile squirrels hiding in the hole and consume almost all of both of them, alone. This paper describes the case of a female chimpanzee to predates on two juvenile squirrels with bare hands and consumes them at MMNP. Further, we explore, compare and discuss the exhibited behavior.

METHODS

Study site

The incident was observed in the habituated M group chimpanzees of the Kasoge forest in MMNP (29°40′0″E to 30°5′0″E and 6°0′0″S to 6°30′0″S; Fig 1). The elevation of the area ranges from 780–2,460 m above sea level, and receives an average annual rainfall between 1,330-2,286 mm, with a mean temperature ranging between 18-29°C (Nishida, 1968; Matsumoto and Kasagula 2000; Nakamura et al. 2015). Three main types of vegetation types found in MMNP include woodland, montane forest, and lowland forest (Nakamura et al. 2015, Chitayat et al. 2021). The dominant species of woodland species in the area include Brachystegia woodland, Combretum woodland, Uapaca woodland, Diplorhynchus-Pterocarpus woodland, Acacia woodland, and Oxyanthera bamboo woodland (Nakamura et al. 2015).

RESULTS

Prey species

The red-legged sun squirrel, *Heliosciurus rufobrachium* (Sciuridae) is usually found alone or in pairs. Nesting takes place in the holes of tree trunks and large branches. The nests are lined with leaves and twigs. Breeding takes place twice a year with usually two per litter (Cassola 2016).

Observation

On 17 August 2016 at 09:36 AM, Baraka Naftal (BN) encountered a party of not less than five chimpanzees along the Kasiha River in the centre of M-group's home range. He spotted an adult female chimpanzee, Fawn (FW), in a *Croton macrostachyus* (Hochst. ex Del.) tree searching for something in a tree hole, removing leaf litter from it with her left hand. The curiosity of the object towards the search convinced BN to keep recording video of the event by using a Nikon Coolpix L840 camera. After a few seconds of searching, FW stopped lowered her head and looked into the tree hole. She remained vigilant for a few seconds, focusing on the hole. After that, FW inserted her right hand again into the hole, removing more leaf litter, and closely concentrating on the hole. At 09:37 AM, FW grabbed a juvenile squirrel with both hands that had fled the hole. FW started biting at its head, killing it immediately. After eating the squirrel for a few seconds, she again focused her attention periodically on the tree hole.

While biting the first squirrel, another one exited from the hole. Using her left hand, she quickly grabbed the second squirrel. The first squirrel was quickly removed from her mouth and held in her right hand, while the second squirrel was killed and consumed similar to the first one. As FW was biting at these two squirrels, a larger individual, probably the mother rushed out from the hole (possibly) and fled. Holding both prey in her right hand, FW checked inside the tree hole with her left hand. She then climbed up further while holding one squirrel in her mouth and the other in her left hand. After climbing a few meters further up the tree, FW sat on a branch and smashed the second squirrel against a tree branch with her left hand. She then held both carcasses in her mouth and continued climbing higher up into the tree. Later she climbed another few meters higher up, and sat on a branch, holding one of the carcasses with her right foot. After a few seconds of sitting on a tree branch, FW started eating the other carcass from the head, followed by the abdominal parts. While eating, she was also picking nearby dried leaves of *Croton macrostachyus* (Hochst. ex Del.), chewing on them with the meat to form a wadge of meat and leaves. She did this for some time sitting on the same branch.

Later, FW grabbed the other squirrel carcass grasped in her foot and held it with the first carcass together in her left hand, taking a bite off the head of the second carcass. Subsequently, FW climbed down, holding both carcasses alternately in her left hand and mouth. She continued to move down, approaching another adult female chimpanzee with a baby, sitting in front of the tree hole where FW had captured the two squirrels earlier. FW submissively reached out and held onto the chin of this adult female. No meat sharing was observed. FW then climbed back up higher, leaving the female who continued to investigate the tree hole. After a few seconds of climbing, FW stopped and started eating the carcasses again. Shortly afterwards, the previous adult female and her baby approached FW. Again, without sharing the carcasses with this female, FW grabbed both carcasses and moved away. FW stopped again at the tree hole nest where she captured the two squirrels earlier. There she spent a few seconds repeatedly inserting her right hand in the hole and peering into it. Finding nothing, she climbed down from the tree with the remains of the carcasses in her mouth.

On the ground, FW walked about 8 m and climbed into another tree where she spent most of the time eating the carcasses, mixing the meat with fresh leaves and dry leaves of *Saba comorensis* into wadge. Then, FW climbed down the tree and moved again for a short distance away on the ground. She then stopped and ate the carcass while mixing it with leaves (Fig. 2). After some time, she continued moving along Kasiha River where she met another chimpanzee, with whom again she did not share meat. Observations were ended at 10:13 AM, by which time FW had consumed almost all the meat alone.

DISCUSSION

In many study sites, females and immature chimpanzee individuals have been less observed in hunting than male chimpanzees. However, solitary and silent hunting attempts by such individuals may have been missed. Habitual tool use by chimpanzees in hunting has been reported from Fongoli and MMNP. However, tool-assisted hunting attempts are rarely observed at MMNP (Nakamura & Itoh 2008). Pruetz & Bertolani (2007) reported that chimpanzees in Fongoli used tools (i.e., sticks) as "spears" in hunting vertebrates. Nakamura & Itoh (2008), an 8-year-old female at Mahale used a stick in a tree hollow to capture squirrel. Following this incident, it was assumed that the use of the stick had injured or killed the squirrel. Huffman & Kalunde (1993) reported that chimpanzees in Mahale used tools as probes or rousing tools during squirrel hunting. Nonetheless, a recent squirrel predation by an adult female chimpanzee at MMNP was not tool assisted (i.e., was a barehanded exploration that was followed by a successful capture of two juvenile squirrels).

The differences in the mechanism used by chimpanzees in different study sites to capture prey elicit more insights on the role of tool use by chimpanzees in vertebrate hunting, when and in what circumstances tools can be used. Comparing the squirrel hunting case by Huffman & Kalunde (1993) and Nakamura & Itoh (2008), we argue that since the recently captured squirrels were juveniles, the hunter did not perceive the prey as dangerous considering that the hunter was an experienced adult female. Unlike juvenile squirrels, adult squirrels may pose serious threats to the hunter. Some factors influence a predator's hunting success rate (Funston et al. 2001) include sex of the predator, body size, age, and group size (Funston et al., 2001); prey species, prey size, defensive ability, escape behaviour, body condition, group structure, habitat etc.; these factors also influence the selection of prey by predators (Funston et al., 2001); and lastly are the environmental factors such as vegetation cover, visibility etc. (Funston et al., 2001). Additionally, intelligence between chimpanzees and social carnivores may all affect the difference in success.

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MAASAI GIRAFFE (*Giraffa camelopardalis*) POPULATION SURVEY IN MKOMAZI NATIONAL PARK, TANZANIA

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ABSTRACT

Tanzania has the highest population of Maasai giraffes (*Giraffa camelopardalis*) among East African countries. Their distribution is limited to protected areas including Mkomazi National Park (MKONAPA). Despite being confined to protected areas, the IUCN considers Maasai giraffes to be endangered, and the population has dropped by 30% due to several threats such as poaching, diseases, droughts and changes in land use. Assessing their population dynamics, distribution, food preference and health condition of Maasai Giraffe in MKONAPA is critical for understanding their welfare. Ground survey was used to assess food preference and health condition of Maasai giraffes. Also, photograph mark-recapture method was used to assess the population dynamics, distribution of giraffe in MKONAPA. A total of 422 Maasai giraffes were encountered during the survey, with an average sex ratio of 1:1.5 and average age ratio of 1:2:6 (per group). Most giraffe were found feeding in dense Acacia commiphora bushlands, near water sources and their population was stable with representatives from all age groups. Direct observation was made for any clinical signs but none had skin or ear diseases. Threats assessment was made and found that most giraffes were affected by drought. Additionally, information on the Maasai Giraffe's population dynamics has provided critical locations for their conservation in MKONAPA and a baseline information for long term monitoring. Therefore, population dynamic and threat assessment are crucial for giraffe viability and successful conservation efforts to ensure long-term existence in MKONAPA.

Key Words*:* Giraffe distribution, giraffe population, maasai giraffe, threats

INTRODUCTION

A thousand decades ago species of giraffes were found throughout the African continent, unfortunately climate change and formation of the Sahara Desert, forced them to extinct in North Africa (Strauss et. al. 2015). Giraffe population in the sub-Saharan Africa are widely spread and found in most parts where there is suitable habitat, while on the other parts of the continent their population is reported small, fragmented and declining (Okello et. al. 2015). They strive in the savanna landscape which offers them almost everything they need from tender leaves to shrubs, preferably acacia trees (Okello et. al. 2015). Also, they get water from fodders and going for few days without drinking water. In contrast, being the tallest animal in the Tanzania's Savannah habitats, gives them an advantage over other browsers in the landscape. They reduce feeding competition evolving to exploit niche foraging high in the canopy food sources that are out of reach for others browsers like kudu and impala (Okello et. al. 2015).

In the past decade or so, the estimated number of giraffes was approximately 46,045 in the African continent which were confined in the protected areas, and 140,700 in the entire continent both in and outside protected areas (East, 1998). However, the Rothschild's giraffe was the second most endangered subs species, and it's estimated that <670 individuals with Kenya harboring 60% of them (Okello et. al. 2015). Therefore, change in conservation status from vulnerable to endangered, and the invention of new individual based approach has prompted their population survey.

Among the six-giraffe subspecies found in Africa, MKONAPA harbors the Maasai Giraffe (*Giraffa camelopardalis tippleskirchi*), this subspecies is endemic to East Africa. They are mostly found in small groups because of their social and non-territorial behavior, they collate from 12 to 15 individuals, which last for a short while especially after the females have finished nursing the calves. According to Butynski & Dejong (2009), there has been a huge decline of giraffes' population in the past decade. Also, according to IUCN (2016), about 50% of the total population of giraffe in the past ten (10) years have been lost mainly through poaching, habitat loss and climate change.

The Maasai giraffe is listed as endangered on the IUCN Red List (IUCN 2016). Despite having that status, little is known about Maasai giraffe population status and distribution in MKONAPA hence, leaving a gap in the data on which conservation strategies could be based to monitor their survival and conservation.

DESCRIPTION OF THE STUDY AREA

MKONAPA is located on the northern Tanzania with 3,245 km² in size and bordered Tsavo West National Park (Kenya) in the north. The park has hilly outcrops and mbugas with five main vegetation types. About 75% of the park is covered with Acacia-commiphora bushland, with small patches of 'miombo' woodland. Also, the park has a lowland evergreen forest along River Umba with flat to hilly areas stretching across the park (780 to 1300 m above sea level). The highest areas (> 2300m above sea level) are covered by grassland and montane bushland. These represents habitats suitable for the existence of Maasai giraffes. The Mean annual rainfall is roughly 1500 mm. The Park receives bimodal rainfall i.e., short rains (October-December) and long rains (March–May). Average monthly maximum daily temperatures range from 25ºC to 31ºC average daily minimum temperature ranges from18ºC to 23ºC. Temperatures are highest during the dry season.

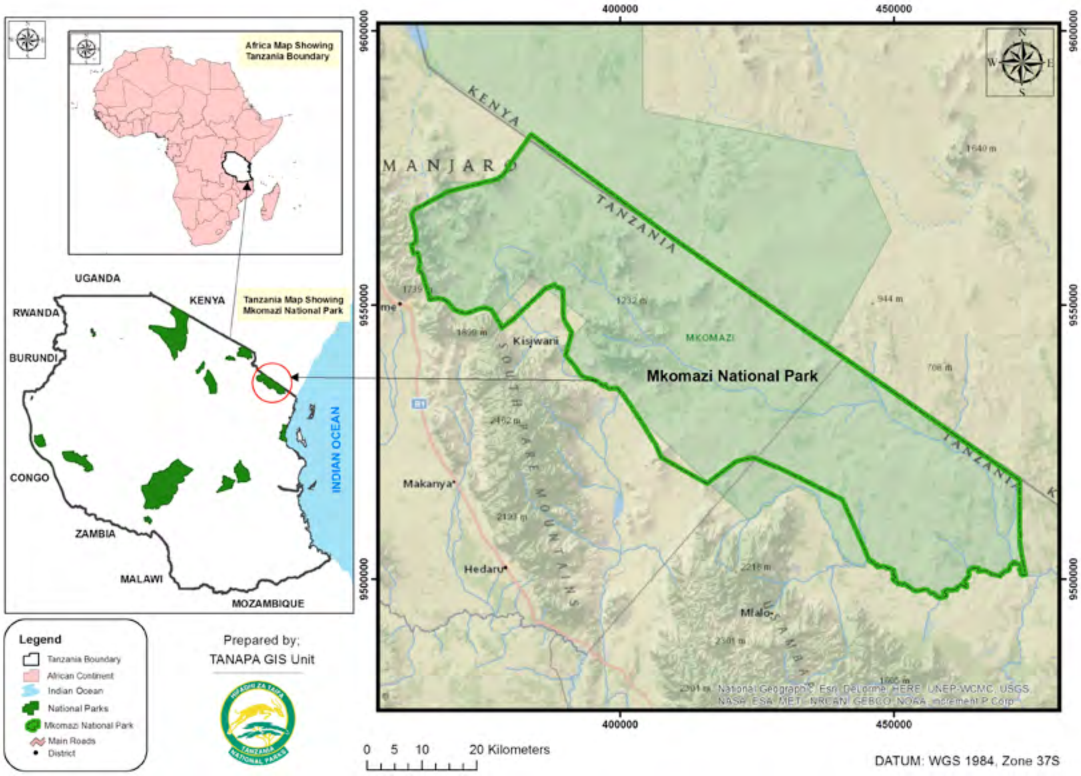

Figure 1: Geographical Location of MKONAPA in northern Tanzania, border with Tsavo West National Park (Kenya)

METHODS

Data collection

Aerial survey was a common method previously used to estimate wildlife population in African savannah (Buckland et. al. 2001), whereas in this study we estimated the Maasai giraffes' population by using photograph capture mark recapture (PCMR) method. This data collection method was used to compliment the common distance sampling methods (Buckland et. al. 2010; Thomas et. al. 2010).

The Maasai giraffes' right side skin patterns are unique as they are fingerprints to human, when estimating their population, we marked both newly and previously observed giraffes by approaching slowly and taking photographs on their patterns (Lee et. al. 2022). A hand-held GPS was used to collect geospatial data to assess giraffe distribution pattern, and direct observation method was used to assess body condition, age and sex (Foster, 1966). Throughout the survey, we used fixed road transects covering an area equivalent to 45% of total park area. We kept an average speed of 22 kilometers per hour and we drove on the chosen roads once per season to avoid sampling biases. During the survey, we estimated the population in wet and dry season. All observations that were detected on the road transects were used in the analysis.

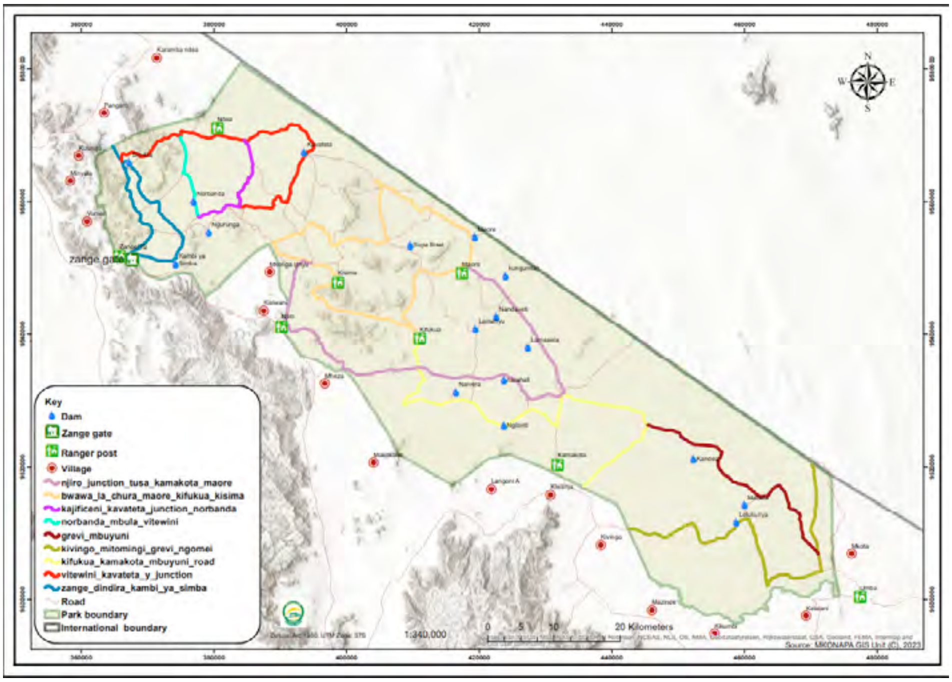

Figure 2: Road transects used during the population assessment of Maasai Giraffe in MKONAPA

Data analysis

Population estimates data of the Maasai giraffe was analyzed by using giraffe pattern recognition software i.e., WILD ID. On the other hand, the collected geospatial data was analyzed by using ArcGIS software version 10.6 (ESRI 2017) to produce a heat map that describes the distribution pattern of Maasai giraffe in MKONAPA.

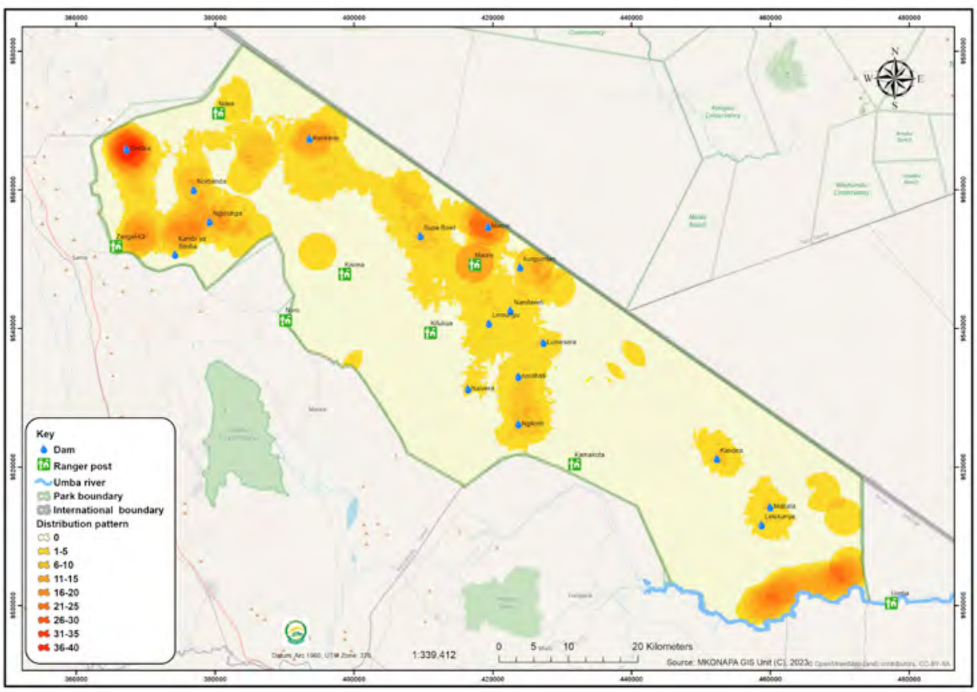

Figure 3: Heat map that shows the distribution pattern of Maasai giraffe in MKONAPA, during the 2023 survey

RESULTS

Population status of Maasai giraffe in MKONAPA

During the field survey, a total of 422 individual Maasai giraffe was observed in the park. Adults number was significantly high (173), followed by sub-adults (138 individuals) and juveniles (111 individuals). The number of adult males was observed high (89) compared with the number of females (84) individuals. The least observed age class was juvenile with 58 female and 53 male individuals (Table 1).

Table 1: Population of Maasai giraffes in MKONAPA, counted during the survey conducted, in 2023

Age and sex group	Juvenile M	Juvenile F	Sub-Adult M	Sub-Adult F	Adult M	Adult F	Total
Total	53	58	82	56	84	89	422
	111		138		173		

Distribution patterns of Maasai Giraffe in MKONAPA

The results showed a significant high number of giraffes distributed in Dindira and Umba areas and few individuals of three all age classes were observed at Kajificheni and Zange areas (Figure 3&4). Age classes showed evenly distribution in all selected areas of the study. Sub adults male and adult females were highly observed in Umba and Dindira areas while there were few observations of juvenile male and sub adult female in Kajificheni and Kavateta areas (Figure 3&4).

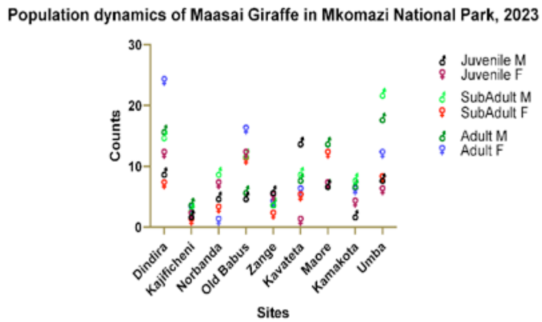

Figure 4: Population dymanics of Maasai giraffe observed during the road count survey, conducted in 2023 at MKONAPA

Sex ratio of Maasai giraffe in MKONAPA

Results showed high number of adult individuals in both female and male and low number of juveniles on both sexes. The sex ratio of male and female for adults and juveniles was 1:1 while for sub-adults was 1:0.5 and for the whole population was 1:1.5 (Figure 5).

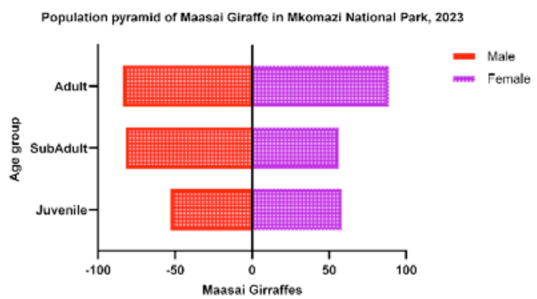

Figure 5: Population pyramid for Maasai giraffe observed in MKONAPA, during 2023 survey.

Threats affecting Giraffe conservation in MKONAPA

The highest threats observed to affect the survival of giraffe in MKONAPA was drought and poaching while the least threat was diseases and habitat loss (Figure 6). Adults and juvenile age classes were highly affected by drought than sub-adults.

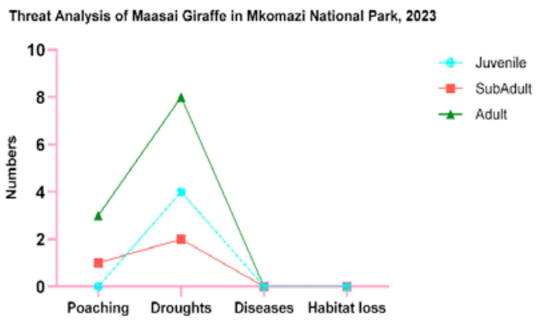

Figure 6: Threats analysis of Maasai giraffe in MKONAPA during 2023.

DISCUSSION

The Maasai giraffe population trend varies between landscapes in East Africa, and Tanzania host a greater share with a total of 28,850 (Strauss et. al. 2015). MKONAPA has a total of 422,that represents 1.48% of the total population of Maasai giraffes found in the country. The reported giraffe population in MKONAPA is a representative of a total estimate of 749 giraffes counted in the aerial survey done in the park by TAWIRI (2019). Large population of Maasai giraffe was observed close to watering points in Dindira and Umba area close to umba river. Age class of Maasai giraffe observed in the entire park skewed to adults, and the drought was the highest threats affecting their survival in the park. No signs of giraffe disease observed during the whole period of field survey in the entire park. Generally, results from this study provides baseline data to develop conservation strategies for Maasai giraffe in MKONAPA.

Large population of Maasai giraffe were locally confined in area with highest density of thorny dominating habitats in the western and eastern parts at Dindira and Umba areas while others were scattered on the eastern parts of the park. Large concentration of Maasai giraffes was observed close to Dindira Dam and River Umba which are watering points capable of holding water throughout the year in the park. The availability of water during the peak dry periods, is a massive determinant of Maasai giraffes' distribution in the park. Similar observation was reported in the Tarangire ecosystem that insufficient water caused higher mortality of giraffe population and reduced a significant number if such anomalies occurring more frequently (Bond et. al. 2023).

At MKONAPA, the results shows that both males and females were highly featured at all age classes to a ratio of almost 1:1. This sort of population with considerable numbers of both sexes, it is considered stable because it's easy for the species to locate a mate. Although the results show population pyramid is skewed towards adults, but also both Sub Adults and Juveniles were well represented, this reduces the risk of extinction. Although we consider the population as stable, they have been some decline in their range, for example Okello et. al. (2015) reported a decline of nearly 70% of Maasai giraffes in Maasai Mara Ecosystem in the past 20 years. they have been eliminated in most of their former range in the last century [9]. In Kenya and Tanzania specifically, their population trend vary from region to re-gion. For instance, there was a 70% decline in Maasai Giraffe in the Maasai-Mara ecosystem of Kenya in a span of 20 years [8], and this was attributed to; land and vegetation changes, increase in livestock, poaching and re-duction in migration opportunities.they have been eliminated in most of their former range in the last century [9]. In Kenya and Tanzania specifically, their population trend vary from region to re-gion. For instance, there was a

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In the past few decades, the population of Maasai giraffe had declined by 50%, attributed mostly to; climate change, habitat loss and poaching (Lee et. al. 2023). From the results, climate change had severe implication on the population status of Maasai giraffe in MKONAPA. Results from this study revealed that during the peak dry season, giraffes suffer by going several days without water. Similar situation was reported in southern eastern Zimbabwe were most adult giraffe deaths occurred because their daily requirements for water could not be met (Mitchell et. al. 2010). Therefore, establishment of population dynamics is a necessary plan to mitigate threats for the species and subsequently enhance their conservation (Anderson et. al. 2007)

Giraffes has a significant role in the landscape, they propagate seeds of different plant species, notably they play a significant role to ensure the existence of acacia species which is their primary habitat. With such uniqueness to other large mammals, its morphological layout remains one of the most attractive species that is found in the landscape. Therefore, we cannot afford to lose such species, more effort is directed towards their conservation. Their population is expected to increase if their threats are reduced, while enhancing science-based management through monitoring the population trend (Okello et. al. 2015).

CONCLUSION

The spatial and temporal results from this study aids the park management to conserve the species and prevent its local extinction. This study provided the current status of giraffe population in the park and has provided the baseline information for monitoring of current population size and their distribution in the park. In MKONAPA, giraffe showed little seasonal differences in distribution, like in Tarangire-West Kilimanjaro ecosystem they were equally widespread throughout the year (Foley et. al. 2018). This suggests that the species migrates less than other larger mammals in the ecosystem, and that many areas have resident populations of giraffe. Therefore, giraffe conservation should be considered a priority because their numbers across both East Africa and Tanzania have been declining (Foley et. al. 2018).

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DIVERSITY AND RICHNESS OF BUTTERFLY ACROSS VARIOUS HABITATS OF MSOLWA SECTOR IN NYERERE NATIONAL PARK, TANZANIA

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ABSTRACT

The study was focused on butterfly diversity and richness among various habitats within five areas namely; Kasungura, Manane, K5, River Ruaha and River Kilombero located in Msolwa, Nyerere National Park. We assessed the richness and diversity of butterfly species within the Nyerere National Park in eastern-central Tanzania to enhance informed decisions on conserving butterflies. Data were collected from November 2022 to March 2023, from 10 plots (5 m×5 m) using sweep nets, banana baited traps and visual observations, across different vegetation types. We analyzed the data using the Shannon diversity index and analysis of variance. Survey was conducted by using the following techniques. GIS mapping and reconnaissance survey were done before habitat selection. Stratified sampling technique was employed in selection of habitats for butterfly sampling in the study area. A traditional transect (pollard walk) of 1km was established in each habitat, walking transects was done at a constant rate of 20 minutes per plot. Total of 10 plots with 5 meters side by side within transect was established systematically with an interpoint distance of 100 meters between 0700 hours to 1100 hours. The results showed that a total of 1037 butterflies from 95 species belong to 4 families were recorded. Butterfly species richness was highest in riverine habitat of Ruaha and Kilombero, and lowest in Marsh vegetation (Kasungura). Mean number of individual butterflies was highest in forest compared to riverine, woodland and marsh habitats. The findings from this study concluded that climatic change, habitat transformation, seasonal burning, and absence of floral resources affect the richness and diversity of butterfly species. Furthermore, the study recommend that more conservation efforts should be employed so as to reduce the likelihood of butterfly species extinction.

Keywords: Butterfly conservation, diversity, richness, Msolwa area, Nyerere National Park

INTRODUCTION

Butterflies are a taxonomically well-studied group of insects, which have received a sensible amount of consideration all over the world (Ghazoul, 2002). Butterfly species have been documented in the meantime at the turn of the 19th century (Bingham 1905, 1907; Williams, 1927). Far along, (Larsen, 1987) made a comprehensive survey of butterflies in the Nilgiri mountains and document about 300 species including endemic one. Many Entomologists have played a great role to significantly improve our understanding about butterfly diversity and abundance (Kunte *et al*., 1999; Arun and Azeez, 2003; Eswaran and Pramod, 2005; Xavier, 2006; Pramod Kumar *et al*., 2007; Krishnakumar *et al*., 2008). Species richness has made Lepidoptera much renowned species due to their ecological roles as pollinators in forest and agro-ecosystems (Pywell, 2011), environmental indicator (Thomas, 2005), phytophagous species (Tallamy, 2004). So, studies had found that vegetations and butterfly diversity are related positively (Thomas et al, 1985; Leps et al, 1990;). So, this study assessed butterfly diversity and richness in various habitats found in Msolwa, Nyerere National Park. Despite the estimated number of butterflies in the park, very little is known about butterfly diversity and richness in Msolwa. Likewise, there is no record of study done on butterfly diversity and richness in Msolwa, Nyerere National Park.

Furthermore, despite their ecological importance as indicator species, few studies have been conducted to document status, species composition, abundance, distribution, diversity and butterfly linkage to their floral resources in most of the Tanzanian ecosystems. Nyerere National Park is renowned as the prime habitat for a high diversity of animals and insects however, there are adequate studies specifically on large mammals rather than small mammals and insects. Hence, information about the butterfly is rarely documented. Therefore, insufficient information about butterfly species richness and diversity have contributed to linger conservation of butterflies within the respective areas.

Species richness has been suggested as a surrogate for ecological indicators in environmental monitoring and evaluation (Larsen 2005) due to their sensitivity to anthropogenic disturbance (Koh 2007). Accordingly, the main objective of this project was to survey butterfly biodiversity of Msolwa ecosystems. More specifically, we aimed to assess butterfly diversity and richness across various vegetation types of Msolwa, in Nyerere National Park. The results generated from this project will offer additional knowledge to butterfly conservation and monitoring, both spatially and temporally.

Research questions

HI; Does the butterfly diversity and richness influenced by habitat type.

HO; Butterfly diversity and richness is not influenced by habitat type.

MATERIALS AND METHODS

Study site

The study was conducted in Nyerere National Park (NNP), which was upgraded from part of Selous game reserve in 2019. NNP is the largest National Park in Tanzania. Nyerere National Park has approximately size of 55,000km square is about 6 percent of Tanzania land surface (Wildlife Division, 2003). The study was conducted in Nyerere National park located at 37^0 03"36' N, 7^0 80"32'E. The annual rainfall of the area ranges between 750 mm to 1250 mm and the mean daily minimum and maximum temperatures of about 21 °C and 29 °C respectively (this study). The area comprises of various vegetation types including miombo woodland, marsh vegetation, riverine forest, riverine woodland, closed and open forest (Jaeger et al., 2014).

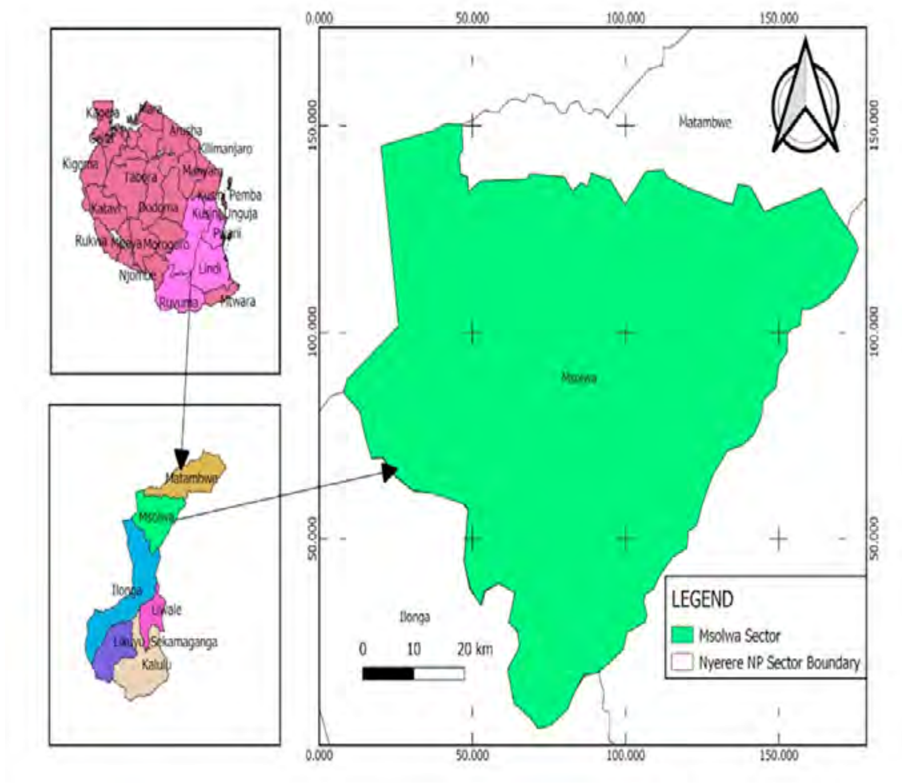

Fig 1: A map of Msolwa area in Nyerere National Park

Sampling of butterfly community

Reconnaissance survey was done before habitat selection. Then, stratified sampling was employed in selection of habitat using GIS in the study area (Rija, 2022). Systematic random sampling was used in laying down transects with plots so as to minimize bias in butterfly sampling and plant survey. A quantitative study was carried out from November to December during the late dry season and February to March for the early wet season. Transect method was employed in accordance to that laid out by Pollard et al., (1977).

A traditional transect (pollard walk) of 1km was established in each habitat, walks on the transects was regularly at a constant rate of 20 minutes per plot. A total of 10 plots with 5metres side by side within transect was established systematically with an interpoint distance of 100 meters. The study area was visited at least every day within the 2 months, during 0700 hours to 1100 hours. Method of sampling was sweep net method, banana baited trap method and observation method so as to minimize effort bias. Sweep net (Balogun et al, 2021) with 2m diameter was used for the low flying butterfly (Nkwabi *et al.,* 2017). To attract fruit feeders' butterflies, blendon traps (Balogun et al, 2021) Banana trap baited with fermented banana prepared 48h prior to trapping (Alexander and DeVries, 2012) was set per every 100 metres. So, each line transect of 1km had 10 points with banana baited traps. This technique was very effective in surveying butterflies and greatly successful compared to sweep net and observation method.Also, observation method was done through observing butterfly in every point after 100m within 1km transect.

Statistical analysis

To understand the composition of the butterfly communities in the study area, the butterfly abundance data were described by categorizing them into families. Sampling completeness was assessed using rarefaction curves. Firstly, a normality test was run on the data before using analysis of variance (ANOVA) to conform to the assumptions of ANOVA tested by using the Shapiro-Wilk test ($P<0.05$). Pooled butterfly abundance data were used to compute species diversity and the analysis of variance was used to explore differences in species diversity between the vegetation types. We calculated species richness estimate by counting number of different species present in each habitat vegetation type. The Shannon-Weiner Diversity index was used to determine diversity among vegetation types. Furthermore, differences in species richness and diversity between the vegetation types were tested using ANOVA.

RESULT.

Butterfly species richness, diversity and habitat preferences

During our survey in Msolwa, a total of 1037 individuals representing 95 species of the order Lepidoptera, belonging to 4 families were observed and identified. The list of butterflies along with their abundance in four vegetation types were recorded.

Species richness and number of individuals were higher in riverine forest (68 species; 414 individuals), followed by miombo forest (66 species; 330 individuals) and followed by woodland vegetation (21 species; 98 individuals) and then marsh vegetation (16 species;195 individuals), Figure 1. Species richness differed significantly across the surveyed vegetation types (Kruskal-Wallis test, $H = 150.5$; d.f = 3; $p \leq 0.0001$).

Figure 2 (butterfly species rarefaction curves) showed that, neither of the curves started to approach an asymptote level, indicating a large possibility of encountering more species in the surveyed habitat types with increasing sampling efforts. Miombo forest had the highest species diversity ($H' = 3.721$) than riverine forest ($H' = 3.617$), marsh vegetation ($H' = 1.727$) and woodland ($H' = 2.742$). The difference was statistically significant. Moreover, species evenness was greater in woodland ($E = 0.7386$), forest ($E = 0.6256$), in riverine forest ($E = 0.5476$) and lowest in wetland ($E = 0.3516$), Table 2

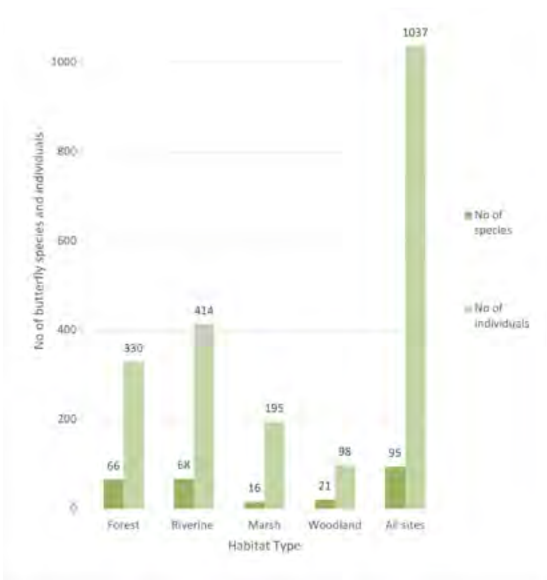

Figure 1: Number of butterfly species and individuals across different habitat types in Msolwa.

Table 2: Summary of diversity indices of Msolwa butterflies

Habitat types				
Diversity Indices	**Forest**	**Riverine**	**Marsh**	**Woodland**
Shannon H	3.721	3.617	1.727	2.742
Simpson_1-D	0.962	0.9578	0.665	0.9203
Evenness_ e^H/S	0.6256	0.5476	0.3516	0.7386

Among the butterfly families, Nymphalidae showed the maximum species number, accounting for 60.41% (n = 58) of the total observed species while Papilionidae was the least dominant, 7.30% (n=7, Table 3). Similarly, family Nymphalidae ranked the first in terms of species number (Woodland, 33 species; Forest, 256 species; Riverine, 263 species and Wetland, 169 species) when study sites were considered independently (Figure 3). Considering the number of individuals across the entire study habitats, family Nymphalidae scored the highest with 70.03% (n = 721), followed by Pieridae 22.53% (n = 226), Papilionidae 4.34% (n = 45) and then by family Lycaenidae with the lowest number if individual, 3.10% (n = 31).

Table 3: Families associated with number and percentage of species and individuals observed in Msolwa

Family	# of species (%)	# of individuals (%)
Lycaenidae	13 (13.54)	31 (3.10)
Nymphalidae	58 (60.41)	721 (70.03)
Papilionidae	7 (7.30)	45 (4.34)
Pieridae	18 (18.75)	226 (22.53)

In Msolwa ecosystems, 38 common, 31uncommon and 26 rare species were recorded. The most common species are *Acraea natalica, Axiocerces harpax, Belenois aurota, Bicyclus campus, Bicyclus ena, Bicyclus safitza, Byblia anvatara, Catacroptera cloanthe, Byblia ilithyia, Catopsilia florella, Charaxes brutus, Charaxes castor, Charaxes jasius, Charaxes varanes, Colotis daira jacksoni, Colotis evagore, Colotis regina, Danaus chrysippus, Eurema brigitta, Eurema desjardinsii, Gnophodes betsinema diversa, Graphium angolanus, Hamanumida daedalus, Heteropsis perspicua, Hypolimnas misippus, Junonia hierta, Junonia natalica, Junonia terea, Leptotes pirithous, Melanitis leda, Papilio democodus, Pardopsis punctatissima, Phalanta, Protogoniomorpha anarcadii, Sallya amulia rosa, Sevenia pechueli and Tirumala petiverana.*

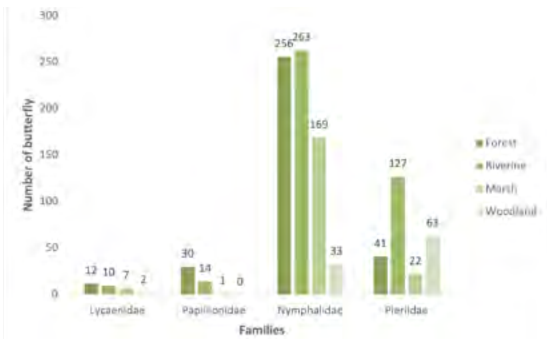

Figure 3: Species number contained in recorded butterfly families in different habitats of Msolwa

DISCUSSION

The association between butterfly and habitat type can be explained by several factors. High level of humidity in the area provides the high ideal environment of butterfly to produce new ones in forest habitat resulting in higher numbers of individuals in this habitat particularly the fruit feeders butterfly. But also, in areas with riverine habitat there high chance of encountering more species of butterfly because of water sources and canopy as well as the floral resources. As some of butterfly species feed on floral resources so there is high chance of the butterfly to multiply their number. The butterfly diversity and richness were significantly different across four habitat types; forest, grassland, riverine and wetland areas. Forest areas in Tanzania are rich in butterflies compared to grassland, wetland and riverine areas (Kielland, 1990).

According to Kielland (1990), Tanzania has seven families of butterfly; the occurrence of 4 families in Msolwa, alone indicates that this place is relatively diverse in butterfly diversity. Forest habitat type exhibited the highest variety or richness of different species compared to other habitat types, followed by riverine (open and closed woodland), wetland, and grassland, which had the lowest diversity. Findings by Fitzerherbet et al. (2006) show that riverine forest was the most diverse habitat types for butterfly. The explanation for higher species diversity in the forest may include; available forest cover, and the significant number of flowering tree species, microclimates, and many butterfly larval associated plant species (Musarandega, 2015) butterflies species diversity.

Nkwabi et al. (2017) highlighted basic patterns at species richness, generic and family levels across five habitat types after standardizing researcher efforts echoing Fitzherbert et al. 2006. First, they found significant low species richness and abundance in grassland, possibly because grassland plain contains fewer trees, shrubs and herbs that provide food for butterflies. Second, the grassland area was affected by human induced fire which reduced number of species in the habitat type. This is similar to the current result which show that, there was indication of butterfly community groups showing greater departure which was associated with the habitats they utilize. Moreover, species diversity was relatively higher in areas with high canopy cover, in trees with smaller DBH and at low ground cover. On the other hand, butterfly richness increased in sites with high tree density and high canopy cover in forest, riverine (open and closed woodland) and less in grassland and wetland habitats. So, butterfly richness tended to increase at high canopy cover and in sites closer to the water source.

Nkwabi et al documented that there is an increase evidence that disturbance has an impact on biodiversity. Some studies (Hill et al. 1995; Lu et al. 2002) have shown that different types and scales of insects including butterfly responds to the same form of disturbance in different ways. Furthermore, higher species richness of butterfly was found to be associated with miombo woodlands than in riverine forest, a possible reason was that butterfly species visit miombo woodland for possibly supplemental nectar resources not found in the adjacent small patches of forest outside the miombo woodland. However extensive removal of the forested areas including bush burning reduces the habitat for butterfly. So, several studies have indicated that the disturbed habitats support poor communities of butterflies.

The overall results have suggested that butterfly diversity and richness was significantly influenced by human disturbance, in line with findings by (Nkwabi et al, 2017) who reported that butterfly abundance and species richness were lower in disturbed habitats than in habitats that have been subjected to little human alteration. Areas with lower disturbance levels such as those which was located near the Selous Game Reserve, and which was found with the lowest level of human disturbance had the highest butterfly species richness. However, the effect of bush burning in Nyerere National Park have resulted to the decrease in number of butterfly species compared to the areas not disturbed by fire. As well as, areas with high floral resources, low temperature and near water sources was significantly contributed to high species richness in the area.

CONCLUSION AND RECOMMENDATIONS

Butterfly species richness and diversity in southern part Tanzania is much higher in wet areas with high humidity, floral resources and low temperature forexample forests and riverine habitat. But also, as the data was collected in variety of season both wet season and dry season.The wet season is more diverse than the dry season. This is an indication that butterfly prefer areas with enough floral resources, low temperature such as forests and near by the water sources such as riverine Ruaha and Kilombero as per areas of data collection. Finding from this study indicates that butterfly in Msolwa are under great threat due to changes in climatic condition and bush burning.

There is a need for giving conservation education to the communities on the importance of conserving biodiversity resource, since national parks can be used for study and training for students in terms of attachments, internships and research projects if are properly conserved. Also, NYENAPA can be potential tourist attractions and activities include bird watching, butterfly viewing, and landscape hiking as well as photographic. More detailed study is recommended in the area i.e. studies of butterflies in both wet and dry seasons, bigger scale, more sampling techniques ie including the use of butterfly traps in order to yield more vigor and reliable results that will help in the proper management decisions of the study area.

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LOCAL KNOWLEDGE AND UNDERSTANDING ON POLLINATION SERVICE IN SMALL SCALE AGRICULTURE: CASE STUDY OF TEMA VILLAGE, MBUKOMU WARD, KILIMANJARO REGION

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ABSTRACT

The majority of global biodiversity is made up of insects and other invertebrate taxa, but little is known of the distributions and abundance of most species and even less is known about their population dynamics and the threats they face. This lack of knowledge concerning the status and trends of majority of species is worrying, but there even greater concern for species that play important functional roles such as pollinators. Pollination is an essential ecosystem service vital to the maintenance of both wild plant and agricultural plants and it tend to increase the value of agriculture products. The agriculture in turn contributes considerably to food security by producing 90% of the world's food, enhancing people's quality of life, and preserving genetic variety in the plant community. The novelty of pollination services, however are threatened by the population reduction of pollinators brought on by anthropogenic changes and limited information on pollination. Fear and revulsion as negative perceptions are often a way of thinking that prevented conservation of pollinators from receiving assistance. Understanding local knowledge and people's perspectives is essential since it can support the conservation of pollinators and effective protection measures. Structured questionnaire was use to evaluate the locals' knowledge and comprehension of pollination services in Mbukomu ward in the Kilimanjaro region with 67 respondents.

The study revealed that local famers` knowledge and awareness of pollinators and the ecosystem service they provide was low and intentional actions to conserve them were not implemented Respondents' understanding of pollination services was influenced by their career, age, and educational attainment. Poor farming management and practices, such as burning, poisoning and forest clearing, were cited by 60% of respondents as the practices the majority likely to endanger pollinator populations. We therefore urge that agricultural authorities to act to ensure local farmers become aware and knowledgeable of insect pollinators and their roles in agricultural productivity.

Key wards: Agriculture, local knowledge, pollinators, awareness, knowledge, services

INTRODUCTION

Insects play a crucial function in ecosystem health and in agriculture land. It contributes to species richness and biotic biomass on earth. Insects deliver ecosystem services such as nutrients recycling, decomposition, bio control and pollination(Ojija and Lewer 2023). Small scale farming is a major source of food production and income in many countries and it employs about 2.1-2.5 billion people globally of which majority live in developing countries (Sawe et al.,2020) it is important in maintaining food security and environmental benefits. One of the benefits of small scale farming system is that they constitute highly diverse semi natural ecosystems through a combination of wild and domesticate plants species. This practice can therefore conserve biodiversity and sustain agriculture production over time (Sawe et.2020).However balancing biodiversity conservation and agriculture production is becoming increasingly difficult for a number of reasons including intensification and simplification process in agriculture land and associated practices such as use of agrochemicals and pesticides, the deterioration of water bodies through fertilization and frequent and homogeneous cutting of grasslands which removes the floral food sources of insects, which results into loss of habitats for insects and other species (Potts *et al.*, 2011)and provide a vital ecosystem service to crops and wild plants. There is growing evidence of declines in both wild and domesticated pollinators, and parallel declines in plants relying upon them. The STEP project (Status and Trends of European Pollinators, 2010-2015, www.step-project.net. Crop pollination is threatened ecosystem service known to affect agriculture production in small scale farms this has raised concerns about the sustainability of small-scale farmer's livelihoods which depend on pollination for agricultural production. According to FAO 90% of agricultural production depends on pollination, and this contributes significantly to food security and to socio-economic status of small-scale household farmers.

The conflict between increased production and conservation of natural habitat that threatens sustainability of ecosystems services including pollination has received attention(Sawe et al., 2020)but small scale farmers are resilient to global decline in pollination service because they have always use agriculture practices that maintain local pollinators on and around their farm land example use of agroforestry system. Consequently, local farmers will most likely tradeoff their traditional agriculture system if they are exposed to different sustainable farming systems with higher short-term returns. Such changes in land practices will most likely lead to changes in land use and potentially pose a threat to pollinators and affect agricultural production as well (Busse *et al.*, 2021) .

According to(Nielsen and Eldegard, 2020) about 80% of Tanzanians population live in rural areas and depend on small scale agriculture for their livelihood and most of them strive to increase their production by use fertilizers, watering and use of quality seeds(Ojija and Leweri2023). Local experience and knowledge shared among the farmers are the main sources of information in pest management as farmers receive little advice from authorities. Moreover, the benefits of pollination service have received little attention most likely due to lack of knowledge, so knowledge about pollination service and economic benefits of pollinators for food production is low among local farmers in our focal area. In this study we therefore carried out interviews with local farmers about their awareness of pollinators and pollination service and their intended actions to protect them.

MATERIALS AND METHODS

Research design

The research included both quantitative and qualitative approaches, with questionnaires being a part of the quantitative strategy.

Study area

This research was conducted at Tema village, in the Mbukomu ward of the Moshi Rural area. Bananas are their main source of food, but they also grow other crops like coffee, maize and beans in home gardens, which are popular in most households The village was selected for the study because agriculture accounts for the majority of their economic activity though the compositionofthenaturalpollinatorcommunity in the study area was poorlyknown and pollination knowledge is low in an area. There are four seasons in the year: a short rain season from September to November, a long rain season from April to May, a dry season from July to August, and from December to January. According to Lyaruu and Lyaruu (2002), tropical mountain forest, bushes, woodland grassland, coffee plantations, maize, and bananas dominate the vegetation of the village.

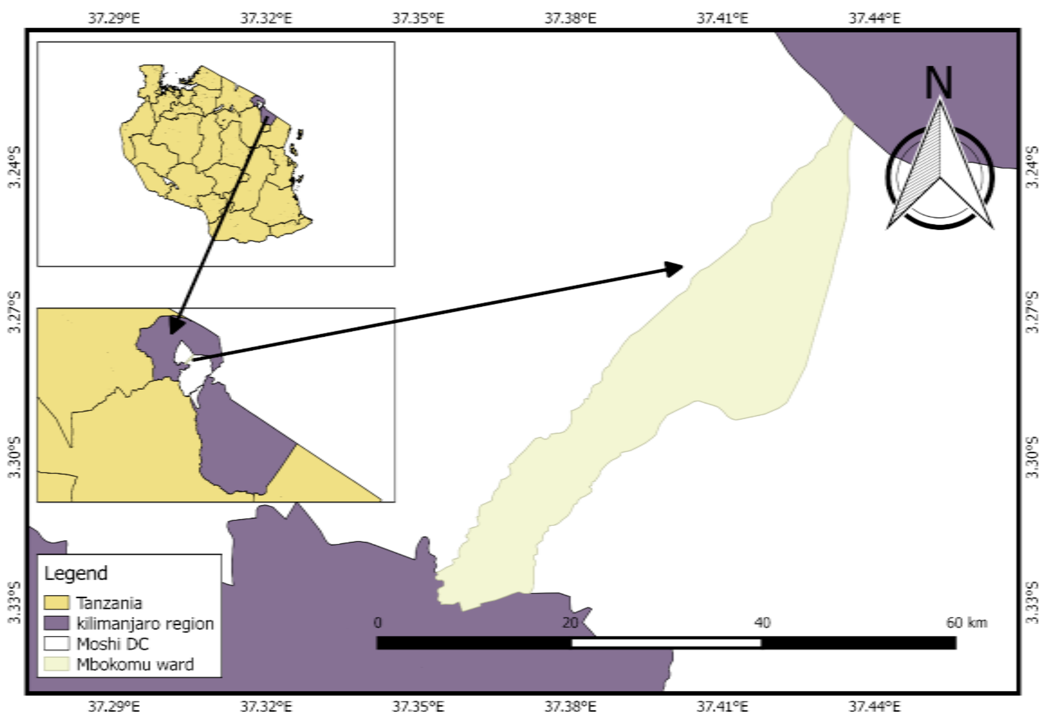

Fig1 Location of a study village (Source QGIS)

Sampling method and sample size

This study used a combination of probability and non-probability sampling. For non-probability sampling, a single village that was studied to represent the entire ward was chosen using cluster sampling. The first household was selected for probability sample using systematic random sampling, while the remaining households were chosen using a fixed interval strategy. The first household was obtained randomly, and the rest households were selected by using an interval of two whereby a random number generator was used. According to Bartlett at al.,(2001), social studies require 5–15% of the overall population and (Kothari, 2004), asserts that the sample shouldn't be too small in order to prevent informational gaps but also shouldn't be too large in order to prevent the collection of pointless data and laborious handling of large samples. Therefore, 15% of households, which is 67 households, were selected as study sample.

DATA COLLECTION METHOD

Primary data collection method

Household questionnaires

In order to gather information about the cultural practices of respondents, the local knowledge and practices that contribute to the conservation of pollinators in the area, the local population was surveyed using both open-ended and closed-ended questions with a range of gender, education level, occupation, and age. Swahili translations of the questionnaires were made to easy communication between enumerators and respondents.

Observation method

The approach was employed to support and enhance the data. This was done in order to find and validate any practices stated by respondents that might impact pollinators or conserve them.

Secondary method

Data was gathered from pertinent published and unpublished sources that were available online and in the libraries.

Data analysis

When there were several responses to a question, before conducting the data analysis, we summed up each response and organized them into variables that best captured the information from respondents. It was feasible to determine how local understanding the significance of pollinators in plant production using descriptive analysis and cross-tabulation. Descriptive analysis was employed to examiningknowledge and practices that endanger pollinators, as well as practices relating to pollinator management and conservation. The statistical package for social sciences (SPSS) and Microsoft Excel were used to carry out quantitative data analysis.

RESULTS

Demographic information

The demographic information that was taken into consideration was age, gender, education level and occupation of respondents whereby a total of 67 respondents of different characteristics were interviewed. Respondents of age (36-45) were mostly participated 41% (n=28), female 61.2% (n=41), secondary education level 38.8% (n=26) and most respondents were farmers 71.6% (n=48).

Table 1. Demographic information of respondents

Variable	Frequency(f)	Percentage %
Gender		
○ Female	41	61.2
○ Male	26	38.8
Education Level		
○ High level education	20	29.9
○ Never attended formal school	9	13.4
○ Primary level	12	17.9
○ Secondary level	26	38.8
Age		
○ 18-25	5	7.5
○ 26-35	19	28.4
○ 36-45	28	41.8
○ 46 and above	15	22.4
Occupation		
○ Farmer	48	71.6
○ Pastoralist	17	25.4
○ Employed	2	3

Local understanding on the role of pollinator in plant production

Examining local perceptions of the function of pollinators was the study's main goal. However, the majority of respondents had limited understanding of the role of pollinators and the pollinators that were commonly used (Figure 2). Different respondents had different understanding of the role of pollinators, whereby the knowledge was affected by different characteristics of respondents, such as education level, occupation, gender, and age of respondents. Bees were the most pollinators which were commonly known and recognized by local community compared to other pollinators (Figure 3)

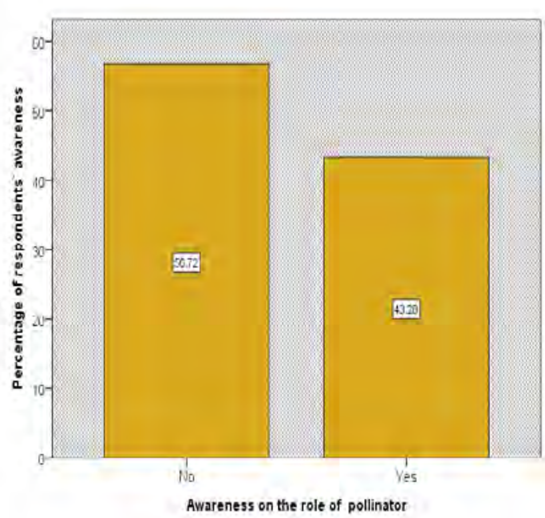

Fig2. Understanding on the role of pollinator

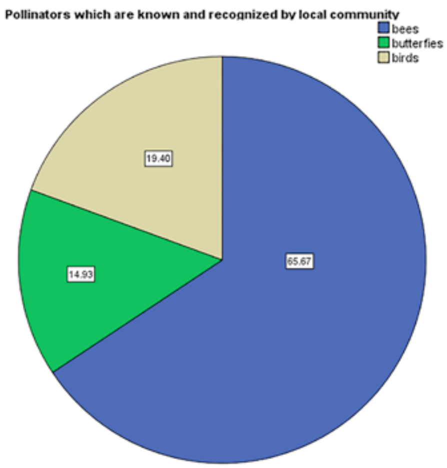

Fig 3. Pollinators which are commonly known and recognized in an area.

Table 2. Understanding on the role of pollinator as affected by different variables

Independent variable	Dependent variable (understanding on pollination service)		PERCENT (%)
GENDER	**YES**	**NO**	**TOTAL**
Female	17	24	**62**
Male	12	14	**38**
			100
EDUCATION LEVEL			
Primary level	2	10	18
Secondary level	15	11	39
Never attended school	0	9	13
High level education	12	8	30
			100
AGE(years)			
18-25	1	4	8
26-35	10	9	28
36-45	18	10	42
46 and above	0	15	22
			100
OCCUPATION			
Farmer	20	28	72
Pastoralist	7	10	25
Employed	29	0	3
			100

Local knowledge and traditional practices that threaten pollinators

Due to different farm management techniques and challenges that farmers face in agriculture like pest, disease and weeds farmers tend to use different ways in combat those challenges and those ways some are not good to insects and they are negatively affect pollinator population as shown in (Fig 4).

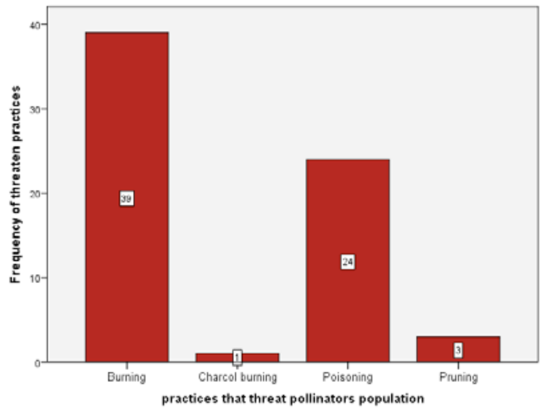

Fig4. Practices that threaten pollinators population

Local knowledge and traditional practices related to pollinator management and conservation

Farmers engage in a variety of activities that improve pollination services, conserve pollinators, and increase plant production. For instance, planting pollinator-attractive plants and engaging in beekeeping activities helps to increase the population of pollinators in the studied village. Over 19% of farmers use traditional practices like use of manure and land use partition in their farming operations.

Table 3: Practices related to pollinator management and conservation

Practices	Frequency	Percent	Valid Percent
Land use partition	9	13.4	13.4
Practicing of mixed agriculture	6	9.0	9.0
Vegetation live fencing	12	17.9	17.9
Use of manure	8	11.9	11.9
Protection and conservation of natural vegetation	1	1.5	1.5
Beekeeping	11	16.4	16.4
Cultivate in small area without affecting natural vegetation	6	9.0	9.0
Use of traditional technology in agriculture	13	19.4	19.4
Planting plants which attract pollinators	1	1.5	1.5
Total	67	100.0	100.0

DISCUSSION

Local understanding on the role of pollinators in crop production

Small-scale farming is the primary economic activity of the majority of the respondents in the research area. The focused factors for production are primarily based on aspects like environment, fertile soil, seeds, pests, and diseases. Farmers had limited knowledge that shortage of pollinators could cause a drop in crop production as also noted by Sawe et al.,(2020). Few respondents were aware of pollination and the role of pollinators because education about pollination and the roles of pollinators was low in the study area. This was demonstrated by the absence of any community efforts to conserve pollinators as well as the current observed limited knowledge among respondents. Farmers do not consider pollinators as another factor which facilitates crop production(Ojija and Leweri, 2023). The majority of farmers (n=57) were found to be unaware of the basic notion of pollination and its implications. Instead, they believed that pollination was one of the processes that trees naturally go through. The study found inconsistencies in the respondents who had the right information were those with some formal education. This can be attributed due to the fact that there are typically multiple pollinator species present and because they change by season and location, certain pollinator species are also unclear to their role (Rhodes, 2018)and to provide pollination services more widely throughout the planetary ecosystems, the prospect of an imminent 'pollination crisis', due to a die-off of flying insects, is most disquieting, to say the least. Indeed, the term 'ecological Armageddon' has been used in the media. However, to know whether or not a wholesale decline in flying pollinators (including non-bee species. Bees are non-selective pollinators, and unlike other pollinators like moths, which do not pollinate food crops and commercial crops like tobacco, most members of the local community could only identify insects as pollinators, especially bees and butterflies. The fact that most respondents were able to identify bees as pollinators was possibly due to the fact that bees were highly common pollinator species in the study area and were used by some households for honey production. As a result, the bees are constantly in contact with people in the everyday environment, which makes it more known to the community members. On a larger scale, it appears that those engaged in beekeeping and honey harvesting appear to gain some knowledge in the course of their long associations with bees and related to flowering and blossoming of flowers to attract insect to themselves in order to make honey, as also reported by Bluwstein *et al.*(2018). The general observation was the prevalence of differences in the overall indigenous traditional knowledge and understanding of pollination across all respondents, depending on their degree of education, gender, age, and education levels.

Local knowledge and traditional practices that threaten pollinators' population

The respondents to the study demonstrated an awareness of a variety of practices that pose a threat to pollinators. Some of these practices were connected to farming practices, including farm management techniques that involve burning off vegetation and residual crops, deforestation that affects pollinator foraging and nesting places, and the use of poisonous agro-chemicals. According to Ojija and Leweri (2023), the use of poison causes insects, including pollinators, to die. It was also found that farmers were more susceptible to using pesticides improperly due to lack of knowledge about insect pollinators and their roles in crop production, as also demonstrated by a study by Sawe et al.,(2020).

Respondents also mentioned honey harvesting as a human activity that obliterates bee colonies and their nesting grounds because some people use fire to chase bees while harvesting honey. Additionally, a lack of knowledge about pollinators and attitudes that disregard them could lead to a fall in the population of pollinators, namely bees. This is due to the fact that some local attitudes toward insects, especially bees, are frequently marked by hatred, fear, and harm, probably because some bees have the potential to sting human(Mcelwee *et al.*, 2020). Furthermore, some respondents thought that bees were bad for flowers because they drained their energy, but few farmers actually understood what bees did when they visited flowers and how crucial bees are to specific crops' ability to produce plants (Bluwstein *et al.*, 2018). Despite this, according to Bluwstein *et al.*(2018), farmers as a whole did not take concrete steps to protect the population of pollinators. Additionally, pollinators like butterflies were described as pests, so people had a bad opinion of both bees and butterflies. Clearly, the lack of understanding and the misguided attitudes of humans regarding pollinators pose a threat to pollinators.

Local knowledge and traditional practices related to pollinator management and conservation

The results revealed that, some respondents indicated their willingness to implement different conservation strategies to safeguard pollinators. These strategies included planting trees, minimizing the use of pesticides by utilizing traditional agricultural techniques, engaging in mixed agriculture, and beekeeping which are compatible activities to their agricultural crops. Additionally, these conservation strategies have potential to accommodate diverse needs of smallholders by, for instance, enabling them to obtain fruits, medicines, and honey while hosting and meeting their specific needs of a variety of pollinators. Additionally, Ojija and Leweri(2023)noted that farmers should use limited pesticides, establish flowering trees and wild flowers for bees to graze on, and leave some land uncultivated to entice bees and other pollinators. Additionally, Sawe et al.,(2020)developed some application techniques for managing pests and diseases in agriculture without having negative impact on the insect population. These techniques include the use of freshly ground leaves that have been mixed and soaked overnight, as well as boiling plant parts and adding soap for extraction (Ojija and Leweri, 2023). To create an extract with a 3%w/v concentration, pound fresh leaves with soap and water(Mcelwee *et al.*, 2020). utilize a different procedure where the material is filtered and chilled to 4 °C before use. Utilizing the knowledge and techniques of pollinator restoration and conservation, farmers undertake their own restoration to enhance the health of the soil and plants. Example Sawe et al.,(2020) demonstrate how many African smallholder farmers have been using various traditional botanical pest control methods to combat insect pests. For instance, in Tanzania, farmers have been using other products like cow urine, cow dung, and ashes in addition to Capsicum frutescens, Nicotiana tabacum, and Tagetes sp. According to the study by Bluwstein *et al.*(2018), some farmers spray pesticides in the evening to lessen their detrimental effects on pollinating insects. This is done to preserve and safeguard insects in the area, including pollinators.

CONCLUSION

By evaluating the public understanding of pollination services and various actions that threaten and protect the population of pollinators, this study aimed to determine the local knowledge on pollination services. The global loss of pollinators was another driving force behind this investigation. The study demonstrated the local community's limited comprehension of the function of pollinators and their scant familiarity with pollination services.

The study also identified certain pollinator-unfriendly habits and several actions that are damaging to pollinators. Additionally, the study creates a knowledge deficit about community programs for pollinator conservation.

RECOMMENDATION

To safeguard pollinators, conservation authorities should implement pollinator-friendly initiatives, such as emphasizing beekeeping and flower plant cultivation. Communities can only actively contribute to providing pollinators with conducive environment that is beneficial to them through awareness raising on pollination service, which can be accomplished through sensitizing communities through launching pollinator conservation programs.Additionally, agricultural authorities including extension officers aim to improve the understanding of pollinators and their critical role as essential free ecosystem service providers among local farmers. Creating programs with a specific goal of increasing farmers' knowledge of the ecological functions and variety of pollinators in both agricultural and semi-natural settings could be one way to put this strategy into reality. In general, creating awareness to the general population on the value of pollination services will bridge the information gap and promote pollinator conservation.

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THE INFLUENCE OF HABITAT TYPES AND WILD ANIMAL EXCRETA ON DUNG BEETLE SPECIES' COMPOSITION IN NYERERE NATIONAL PARK, TANZANIA

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ABSTRACT

Knowledge of the composition of dung beetle species and their association with different habitat types and animal excreta is vital for understanding ecosystem functioning. Dung beetles play a significant role in ecosystem processes, particularly in nutrient cycling. A survey on dung beetle species was conducted to determine how species composition varies across different habitat types and animal excreta in Nyerere National Park, Tanzania. Traps and hand-picking methods were used to capture dung beetles from closed miombo woodland, open miombo woodland, riverine, and marshland habitats. Forty (40 2-Litre baited plastic pitfall traps were placed 50m apart on two linear transects, each with a length of 1km. A total of 5534 individuals, representing 70 different species of dung beetles belonging to 29 genera and 9 tribes were collected and identified. Closed miombo woodland had the highest number of species (39), while the lowest number (22) was collected from the open miombo woodland. In terms of animal excreta contribution to dung beetle species, 42 beetle species were collected from elephant dung, 33 beetle species were collected from buffalo dung, 19 beetle species from hippopotamus dung, and other animals have <5 species. The study shows that a diverse range of habitat types and wild animals distribution play a significant role in determining dung beetle species composition. Therefore it is critical to maintain habitat quality and animal population to ensure the long-term preservation and sustainable conservation of dung beetles in the ecosystem.

Keywords: Animal excreta, dung beetle, habitat type, Herbivores, species composition.

INTRODUCTION

Dung beetles are arthropod that belongs to the order Coleoptera and the Scarabaeidae subfamily (Hanski & Cambefort, 2014). They are globally distributed insects, except in Antarctica (Scholtz & Davis, 2009), with their highest diversity in tropical forests and savannas (Hanski & Cambefort, 2014; Davis et al,2008). There are 7,000 known species of dung beetles worldwide (Hussain et al., 2016), with more than 2,000 species in the South of the Sahara. They are known to live exclusively on the excrement of many different species of animals primarily on herbivores excrement (Doube, 2018; Raine & Slade, 2019). The diversity, species composition, and spatial distribution patterns of dung beetles are strongly influenced by both biotic and abiotic variables (Daniel et al., 2022; Davis & Scholtz, 2001; Davis et al., 2020; Doube, 2018). Biotic factors such as mammal diversity and vegetation cover, as well as abiotic variables such as soil type and temperature, impact the diversity and spatial distribution patterns of dung beetles (Daniel et al., 2022; Davis et al., 2020; Sands et al., 2022). Mammal species' composition and abundance are particularly crucial in determining their distribution (Davis et al., 2008; Raine & Slade, 2019). The majority of dung beetles feed primarily on animal excreta, specifically mammal dung and are also capable of using carrion, rotting fruit, fungi, and decaying plant matter(Hanski & Cambefort, 2014; Daniel & Davis, 2023). Adult dung beetles filter out the nutritious liquid components of the dung pats, while the larvae masticate the larger fibrous fragments, primarily consisting of cellulose. As a result of manipulating dung during the feeding process, dung beetles provide a series of ecosystem functions including but not limited to dung removal, secondary seed dispersal, nutrient cycling, and parasite suppression. Many of these ecological functions provide valuable ecosystem services such as biological pest control, soil fertilization, and reduction of greenhouse gas emissions (Nichols et al., 2008; Raine & Slade, 2019; Scholtz et al., 2009). Based on the type of food relocation and nesting pattern, dung beetles are classified into four major functional groups: Tunnellers (paracoprids) dig vertical tunnels beneath the dung pile; rollers (telecoprids) move a portion of the dung horizontally and bury it after a certain distance; dwellers (endocoprids) do not relocate any portion of the dung pile either vertically or horizontally; and stealers (kleptocoprids) parasitize the nests of other beetles, primarily tunnellers or rollers (Doube, 1990; Hanski & Cambefort, 2014).

Furthermore, dung beetles have been proposed as bioindicators due to their response to anthropogenic disturbances, such as habitat change and mammalian biomass loss (Nichols et al., 2008). However, despite the ecological significance of dung beetles, their species composition and the relationship with habitat types and animal excreta in protected areas like Nyerere National Park have not been explored. Unlike mammals and birds, dung beetles are not considered in the management and conservation programs of these areas, even though they have a wide range of habitats that support a variety of grazing mammals whose dung serves as a crucial resource for dung beetles. In addition to that, studies review that the diversity of dung beetle was higher in protected areas compared to disturbed areas(Stanbrook et al., 2021), where they participate in natural processes of plant regeneration by consuming and burying large amounts of dung and seeds (Muhirwa et al., 2018; Stanbrook et al., 2021). Therefore, the findings of this study hold great value in informing and guiding conservation efforts aimed at protecting beetles and other small decomposing arthropods. We expect that different habitat types and excreta will support unique dung beetle assemblages, with areas of high wildlife activity supporting greater species diversity due to increased resource availability. We sought to answer the following questions: First, how does the composition of dung beetle species vary between different habitat types? Second, is there a difference in the composition of dung beetle species from different wildlife excreta?

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in four different habitat types within (Msolwa sector) of Nyerere National Park, Tanzania. Nyerere National Park is the largest park in Tanzania, established in November 2019, and covers an area of 30,893 km^2 (TANAPA, 2020). The Park covers a large portion of the Liwale District in the Lindi Region's west, Pwani Region's southwest, Ruvuma Region's northeast, and Morogoro Region's southeast, and it is about 35 to 1450 meters above sea level (Fig.1). The Park has a bimodal rainfall season, with short rains in November and December followed by partial drying in January and February, then come the long rains, which last until early May, the average temperature is around 21.4 °C and 33.3°C (TANAPA, 2020). The Park has a wide range of habitats, including Miombo woodlands, *Vachellia* Savannahs, open grasslands, marshes, and riverine forests that host a large population of Africa's most numerous mammals and reptiles, such as buffalo, elephants, hippos, and crocodiles. In addition to that Nyerere National Park, is well known for housing other wild animals, including wildebeest, sable antelope, eland, greater kudu, waterbuck, hartebeest, zebras, reedbuck, giraffes, warthogs, and wilds dogs, that are a principal source of dung for dung beetles. Nyerere National Park encompasses a variety of landscapes and ecosystems, which in turn give rise to different soil types, including black cotton soil, alluvial soils, sandy soils, and red soils (Bruda Evaristo,Persn. obs).

As a result of the park's persistent preservation status and abundant variety of mammal species, coupled with its diverse range of soils (ranging from sandy, well-drained to clays and black cotton soils in varying proportions) and vegetation cover (ranging from open woodland to areas with dense canopy), it presents an ideal opportunity to conduct our research exploration within this park.

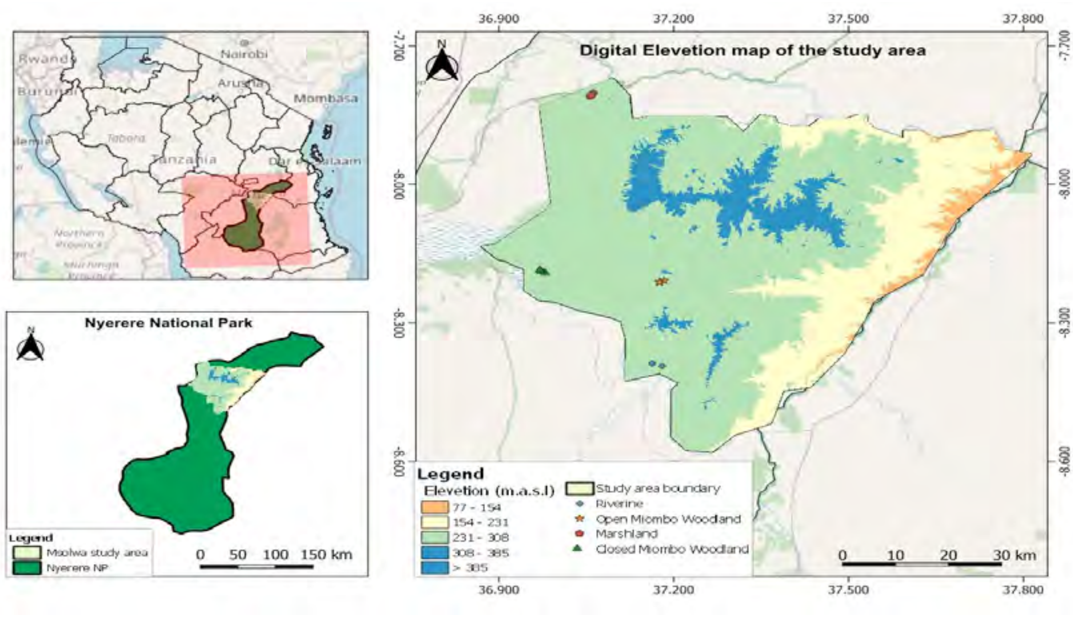

Fig. 1. Map of study area with sampled habitat type

Trapping Methods

Both dry and wet season sampling of dung beetle was conducted between November to December 2022 and February to March 2023. The habitat types including Marshland, closed miombo woodland, open miombo woodland, and riverine, were selected based on the reconnaissance survey done while taking into account a combination of the external appearance of vegetation, its vertical structure, and the growth forms of the dominant taxa (Box & Fujiwara, 2013). Trapping and hand collection methods were used to capture different species of dung beetles in each habitat. Hand collection was done using a small shovel and forceps to pick up beetles encountered within the dung pile. At each selected trapping site in each habitat, forty plastic pitfall traps of 2L were placed 50m apart on a linear transect, with two transects per habitat, and the transects were placed approximately 200m from each other. The traps were buried in the ground so that the top rim was flushed with the soil surface. Each site comprised two transects of twenty traps and trapping was conducted for four consecutive days per transect to provide a trapping effort of eight days per site, yielding a total of 320 samples per location and 1280 collections for analysis. The traps were baited with 40g of fresh buffalo dung, which was readily available. The dung was fine-fibered and had higher moisture and volatiles, making it attractive to many dung beetles (Raine & Slade, 2019; Tshikae et al., 2008). The bait was wrapped in fine gauge mesh netting which allowed dung volatiles to be emitted while excluding dung beetles. The bait was supported above each trap by a tripod of stakes and secured by string. All pitfall traps were half-filled with a soapy solution plus 1.5L of vinegar to ensure that beetles did not escape from the traps while minimizing the deterioration of the captured specimens.

Dung Beetle Identification

Dung beetles were mounted, sorted, labeled, and identified to genus and species level by using a taxonomic identification key(Gordon & Barbero, 2008), beetle pictorial guidebook(Davis et al., 2020), and unpublished species taxonomic list. Where species identification was not possible, beetles were sorted into morphospecies according to their external morphology. Voucher specimens were deposited at the Entomological Collection of Tanzania Wildlife Research Institute (TAWIRI).

Data Analyses

To determine the species richness, composition, and Shannon diversity index, we employed R software version 4.2.3. The analysis was carried out by using a vegan package (Oksanen et al., 2020). Species richness was calculated by recording the total number of different dung beetle species present in each habitat type. Additionally, the composition of dung beetle species within each habitat was determined by specifying the abundance and distribution of each species. To quantify diversity, the Shannon diversity index was employed. This index incorporates both the number of species and their relative abundances, providing an overall measure of biodiversity within each habitat type.

RESULTS

A total of 5534 dung beetles were captured and identified, belonging to 29 genera,70 species, and nine tribes (Autechini, Canthonini, Coprini, Gymnopleurini, Oniticellini, Onitini, Onthophagini, Scarabaeini, and Sisyphini). The highest number of species (39) was found in the closed Miombo woodland habitat, while the lowest number (22) was found in open Miombo woodland with the highest abundances compared to other habitat types (Table .1). In terms of species diversity closed miombo has the highest diversity followed by marshland and riverine (Fig.2). We found that the highest number of species (42) was associated with elephant dung, followed by buffalo dung (33) and hippopotamus dung (19), while others animals dung contributes less than 5 (<5) species of dung beetles.

Table 1. Species composition from all four habitat types, MS (Marshland land), CMS (Closed Miombo Woodland), OMW (Open Miombo Woodlands), and RV (Riverine).

Genus /species	**MS**	**CMW**	**OMW**	**RV**
Autechini	2	3		
Pedaria brancoi	2	3		
Canthonini	1	3		
Chalconotus convexus	1	3		
Coprini	47	72	7	153
Catharsius sp. 1	12	4		9
Catharsius tricornutus		32		
Copris bootes	2	3		
Copris denticulatus			4	
Copris evanidus		20		
Copris fallaciosus	1	10		
Copris obesus	32	3		141
Copris sp.1			3	3
Gymnopleurini	3	11	3164	599
Allogymnopleurus splendidus			4	
Garreta nitens			2	
Gymnopleurus ignitus	3	11	3	6
Gymnopleurus sp.1			3155	593
Oniticellini	65	52	19	12
Cyptochirus ambiguus	2			
Drepanocerus patrizii	13	5		
Euoniticellus intermedius	19	4	5	3
Euoniticellus triangulatus	2			1
Ixodina abyssinica	3			
Latodrepanus laticollis			1	
Liatongus militaris	*24*	19		
Oniticellus formosus	2			8
Oniticellus pictus		2		

Genus /species	MS	CMW	OMW	RV
Oniticellus planatus		10	3	
Tiniocellus spinipes		12	10	
Onitini	52	49	28	12
Cheironitis sp.1				2
Cheironitis sp.2				3
Heteronitis castelnaui				4
Onitis alexis	52	40	28	1
Onitis confusus		4		
Onitis mendax		5		
Onitis sp.1				1
Onitis viridulus				1
Onthophagini	67	283	350	382
Caccobius histerinus			2	
Caccobius nigritulus	1	21		
Caccobius obtusus			1	
Caccobius sp.1				74
Caccobius sp. 2		4		
Cleptocaccobius convexifrons			111	6
Digitonthophagus gazella		13	181	
Digitonthophagus sp.1				2
Euonthophagus carbonarius	3	55	22	9
Hyalonthophagus alcyonides		2		
Onthophagus aeruginosus		1		
Onthophagus bicallosus	9	1		2
Onthophagus ebenus	10	14		
Onthophagus flavolimbatus	7	21		13
Onthophagus herus	1	10		
Onthophagus lamelliger	4	15		40
Onthophagus plebejus	12	73	6	28
Onthophagus politissimus				2
Onthophagus pugionatus	1			
Onthophagus sp.1	2	24		
Onthophagus sp.2		8		72
Onthophagus sp.3		5	1	2
Onthophagus sp.4				2
Onthophagus venustulus				26
Onthophagus vinctus	5	15	26	87
Phalops ardea	1			

Genus /species	MS	CMW	OMW	RV
Phalops flavocinctus				1
Proagoderus furcifer	*2*			
Proagoderus quatrituber	1			
Scarabaeini		20		
Kheper		20		
Sisyphini	1	27	20	30
Neosisyphus confrater		3		
Nosisyphus infuscatus		1		
Neosisyphus sp .1			8	
Sisyphus alveatus				3
Sisyphus goryi	1	23	7	27
Sisyphus sp .1			5	
Richness	31	39	22	32
Richness %	25	31.45	17.74	25.81
Abundance	238	520	3588	1188

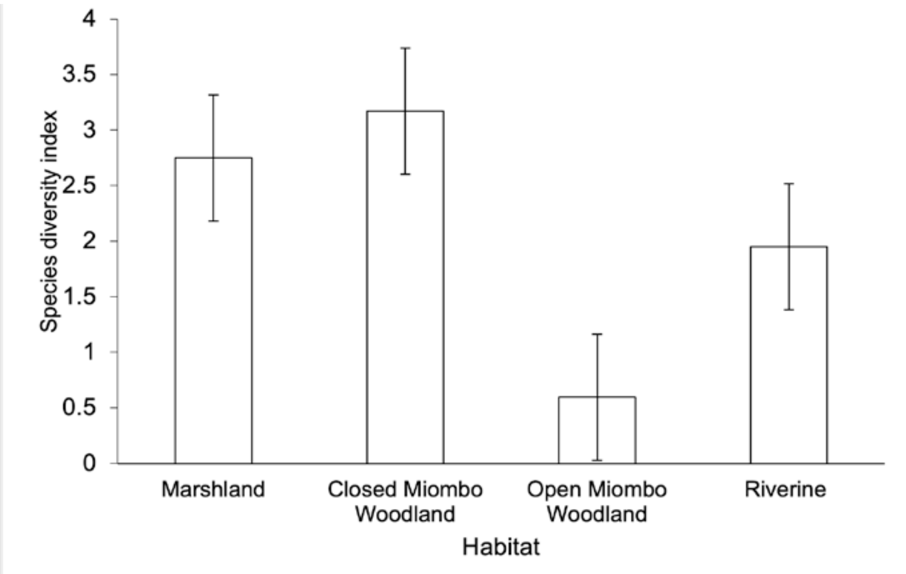

Fig. 2. Species diversity (Shannon Weiner index (H)) in different habitat type

DISCUSSION

Our findings suggest that habitat type plays a significant role in determining the composition of dung beetle species in Nyerere National Park, with the closed miombo woodland habitat having the highest diversity of species. This could be due to the greatest shade associated with vegetation**,** specifically during the dry season when most of the habitats are burned, and forests act as a refuge for animals(Davis et al., 2020). Lower diversity observed in open miombo woodland is primarily influenced by fire, particularly during the dry season when the habitat experiences burning. This leads to bare ground without grass, causing a lack of forage for wild animals and resulting in the shifting of these animals to either marshland or riverine. Consequently, the dry conditions are unfavorable for the activities of beetles, as the encountered dung was completely dry without the fluid content which is mostly utilized by beetles (Tshikae et al., 2008). Conversely, the wet season in open miombo woodland was associated with a higher population of individuals compared to other habitat types. This can be attributed to the presence of an open canopy, allowing more sunlight to reach the understory. Additionally, the grass layer in this woodland type was more abundant and palatable to many herbivores, which serve as a primary source of dung for dung beetles. Moreover, there is typically a lower amount of leaf litter and woody debris on the ground, creating an ideal environment for dung beetles to roll their brood balls.

The presence of water and tall grasses in marshland during the wet season creates unfavorable conditions for animals, which in turn affects the composition of dung beetles. The marshland environment and grasses are not efficiently utilized by animals during this period, unlike the dry season when marshland provides water and palatable grasses to herbivores. Furthermore, the accessibility and utilization of dung by beetles were impacted, as water levels increased and dung pats were submerged by moving water. In contrast, the riverine habitat provides a water supply to animals and foraging opportunities with grasses, herbs, and forbs. The presence of open areas, often associated with short tree species like *Combretum molle*, and *Dalbegia melanoxylon* enables animals to detect predators while foraging. This dynamic directly influences the optimal number of dung beetle species, as there is a constant supply of dung along the river, typically within a range of 100 to 500 meters from the riverside.

In terms of animal excreta most species were attracted to similar dung sources over a short time, this implies that they have very similar ecological requirements, preferences on resource use, and partition as a consequence of a clear hierarchy in their abilities to compete for dung. There is a higher abundance of tunnelers and dwellers on fine-fibered dung of ruminant herbivores dropped as pads (buffalo) and a higher abundance of rollers on pellets of ruminant herbivores (wildebeest, zebra, heartbeats, and waterbuck) and coarse-fibered dung of nonruminant herbivores (elephant and hippopotamus), this indicates that tunnelers and dwellers are attracted to fine fibered dung while rollers are associated more with coarse fibered dung, thus might be as a result of dung relocation strategy and morphological characteristic, where most rollers have long and slender middle and hind tibiae, but dwellers and tunnellers have short and broad middle and hind tibiae (Krell, 2011). However, most individuals were discovered in dung that was not too fresh, the number of beetles rises at least 24 hours after the droppings, and beetles start to decline as dung heaps start to dry up. This shows that while variations in the digestive systems and gut microbial in dung beetles as a factor in determining feeding preferences, volatiles are assumed to be an important factor in determining the attractiveness of dung-to-dung beetles(Estes et al., 2013; Franzini et al., 2016; Shukla et al., 2016a, 2016b; Simmons & Ridsdill-Smith, 2011).

These results correlate with previous studies conducted in other regions, which have shown a relationship between mammal species composition and dung beetle abundance(Raine & Slade, 2019), the chemical composition of dung) and the abundance and composition of dung beetles(Davis & Scholtz, 2001). (Estrada et al., 1999) reported a positive association between non-volant mammal richness and abundance and both dung beetle species richness and abundance, in continuous tropical forests, forest fragments, and plantation forestry sites. Physical attributes, quantity, condition of the dung, age of the dung, type of dung produced whether it is from an omnivore and strongly odiferous, or less odiferous from non-ruminant or ruminant herbivores, and whether the latter produced lumps of dung or pellets, determine the potential colonizers (Tshikae et al., 2008). Therefore, dung beetles are thought to have evolved and diversified in response to the adaptive radiation of mammals during the Cenozoic Era due to their close ties to the mammalian fauna (Hanski & Cambefort, 2014). The diversity of dung beetles has been linked to mammal diversity (Nichols et al., 2009). Thus, understanding the association between dung beetles and their resource use is vital in maintaining ecosystem services offered by dung beetles, concerning the current decline of mammal populations and biomass that has the potential to ripple through ecosystems, reducing dung beetle body size and species richness (Griffiths et al., 2016). Large mammalian herbivores exert significant influences on the structure, composition, and functioning of terrestrial ecosystems on a global scale. Their pivotal role in shaping ecological dynamics is demonstrated by many species that rely on them for their survival or overall well-being. As highlighted by(Ripple et al., 2015).

CONCLUSION

This study provides important information on the composition of dung beetle species in relation to habitat types and wild animal excreta in Nyerere National Park, Tanzania.The results suggest the importance of maintaining a diverse range of habitats and conserving wild animals in the park to promote the conservation of dung beetle species and the overall biodiversity of the ecosystem. These findings also have practical implications for farmers and land managers, as they highlight the importance of maintaining nutrient-rich soils by promoting a healthy dung beetle community through ensuring environmental stability and regulating land use along grazing areas that provide resources for the beetles. Overall, this study contributes to the understanding of the functional importance of dung beetles in ecosystems and provides useful information for the management and conservation of these important species.

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HEALTH ASSESSMENT OF GIRAFFES IN ARUSHA NATIONAL PARK

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ABSTRACT

Giraffes are ruminant animals endemic to the African continent. In Tanzania, their population is observed to decrease and it is estimated that there are approximately 33,000 Maasai giraffes, which leads to the species to be listed as endangered by the IUCN. A study on assessing their health condition was done in ANAPA where drastic giraffe population decline from 95% to 49% has been observed. The study was done in two clusters from Ngongongare gate to Nasula gate and Momela gate to Momela Lakes with the main objective of assessing physical body health condition and assess the level of gastrointestinal parasite infestation. Health assessment was done through direct observation and gastrointestinal parasite assessment was done using a formol-ether sedimentation technique. The parasite eggs were concentrated and observed under the microscope.

The data collected were entered into Microsoft Excel and then analyzed by R studio software version 4.0.3. Descriptive analysis was used to describe the physical body health condition of the observed giraffes while repeated ANOVA was used to analyze the level of gastrointestinal parasite infestation in sampled giraffes and the statistical significance was set at $p<0.05$. The physical health condition of giraffes was found to be good by 89.7% while different gastrointestinal parasites eggs were found. Such parasite eggs included Stongyloides sp 27.8%, Trichostrongylus sp 24.6%, Trichuris sp 13.1%, Ternidens sp 18.0%, and Molineus sp 11.5% whereby the p-value was found to be $p = 0.0494$ less than the significance level.

In conclusion, gastrointestinal parasite infestation in giraffe population remains a major health challenge affecting the giraffe in the park. This might be attributed to high interactions between giraffes, domestic animals, and humans.

Keywords: Arusha National Park, Giraffes, gastrointestinal parasites and health

INTRODUCTION

Giraffes (*Giraffa camelopardalis*) are large, endemic ruminant animals native to Africa (Lee *et al.*, 2023). Both sexes have skinned horns and long necks, and they disperse seeds, create open habitats, encourage the growth of new forage, and indirectly pollinate a variety of plants while foraging (Connor *et al.*, 2019). Giraffes are essential to the health of ecosystems.

They have a long prehensile tongue used to browse shrubs and trees in the wooded grassland. There are four taxonomically distinct species with five subspecies, namely the Masai giraffe (*Giraffa tippelskirchi*), reticulated giraffe (G. *reticulata*), northern giraffe (G. *camelopardalis*) with subspecies G. *c. camelopardalis*, G. c. *antiquorum* and G. c. *peralta*, and southern giraffe (G. *giraffa*) with the subspecies G. g. *giraffa* and G. g. *angolensis* (Dunn *et al.*, 2021).

The conservation status of the giraffe species is listed as vulnerable, endangered, and of some least concern by the International Union for Conservation of Nature IUCN Red List in 2016. In particular, the populations of G. *tippelskirchi*, G. *camelopardalis*, and G. *reticulata* have decreased by more than 50% (vulnerable) (Dunn *et al.*, 2021). This indicates that conservation of these species are of major concern. In 2018, the conservation status of G. *reticulata* and G. *tippelskirchi* was evaluated for the first time, and both species were classified as endangered. According to (Dunn *et al.*, 2021), G. *giraffa* species and G.*g. angolensins* are the giraffe species that are of least concerned.

The giraffe population in Africa has decreased from 157,000 in 1985 to 97,500 in 2015 (Muller et al., 2018), with the worst declines occurring in the Masai, Kordofan and Reticulata, Masai with a subspecies (*G. c. tippelskirchi*) and species (*G. tippelskirchi*) distributed to Tanzania, Luanga Valley in Eastern Zambia and Southern Kenya, Kordofan a sub specie of Northern giraffe distributed in Central Africa (D'haen et al., 2019) in Democratic Republic of Congo, and Reticulated species distributed in Northern Kenya, parts of Ethiopia and Somalia (Connor *et al.*, 2019).

According to Tanzania Wildlife Research (TAWIRI, 2021) the number of giraffes in Tanzania is estimated to be 33,000 giraffes. Human actions including unlawful hunting, habitat destruction, and illnesses are to blame for this (Profile, 2016). In different national parks, a decline in the giraffe population has also been noted. Because they leave the park and become vulnerable to poaching and infectious diseases from livestock. Giraffes in Arusha National Park have seen a drastic population decline from 95% to roughly 49%(Lee *et al.*, 2023). Since the giraffe population in Arusha National Park is observed to decrease, health factors might be among the factors that leads to population decline, therefore this study aims at assessing the role of disease in conservation of Giraffe in Arusha National Park.

PROBLEM STATEMENT AND JUSTIFICATION

The presence of giraffes in Arusha National Park has long been regarded as one of the park's main attractions because of the animals' stunning physical attributes and eye-catching hues (Lee *et al.*, 2023). Due to the giraffe's significance in Tanzania in numerous ways, its conservation is crucial, first and foremost, the giraffe serves as Tanzania's national animal and serves as a significant emblem of the nation's natural heritage (Conservation research framework, 2020).

However, due to habitat loss and fragmentation, poaching (illegal hunting), diseases, and ecological change, giraffes

(Giraffa spp.) have experienced a reduction in both distribution and quantity over the past century. There are currently believed to be 117,000 giraffes in the wild (Bernstein-Kurtycz *et al.*, 2023). Skin disease has also been noticed in many giraffe populations throughout Africa including Tanzania. Different National Parks in Tanzania has reported the giraffe skin disease (GSD) which is believed to be caused by the nematode which affects numerous G. *Camelopadalis* species in Tanzania (Bernstein-Kurtycz *et al.*, 2023).

Many studies have been conducted in Arusha National Park giraffes including understanding on attitudes of local communities surrounding Arusha National Park toward giraffes (Mahenya et al., 2020), Masai giraffe population change over 40 years in Arusha National Park (Lee *et al.*, 2023), Sex differences in Giraffe feeding ecology (Young and Isbell, 1991)with open vegetation having female-biased groups, and tall, thick vegetation having male-biased groups. On a ranch in south-central Kenya, we quantified habitat differences of male and female giraffe groups and showed that the preference for open habitats by female groups was limited to groups with young. We suggest that this difference is due to the avoidance of predators of young giraffes. We also showed that rates of giraffe feeding peaked at intermediate feeding heights equal to approximately 60% of adult giraffe height. In the dense habitats with a variety of tree heights used by male groups and female groups without young, both male and female giraffes fed most at heights where they could feed fastest. However, in the open habitats used by female groups with young, females fed mostly at heights below optimum because these habitats are dominated by short food plants. On the other hand, the dominant males accompanying these female groups fed at heights above optimum on rare tall trees, possibly to increase intrasexual vigilance. Apparently, both male and female giraffes sometimes forfeit feeding efficiency tor short-term reproductive gains. 1991 Blackwell Verlag GmbH”,”author”:[{“dropping-particle”:””,”family”:”Young”,”given”:”Truman P.”,”non-dropping-particle”:””,”parse-names”: false,”suffix”:””},{“dropping-particle”:””,”fami ly”:”Isbell”,”given”:”Lynne A.”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:”” }],”container-title”:”Ethology”,”id”:”ITEM-1”,”issue”:”1-2”,”issued”:{“date-parts”:-[[“1991”]]},”page”:”79-89”,”title”:”Sex Differences in Giraffe Feeding Ecology: Energetic and Social Constraints”,”type”:”article-jou rnal”,”volume”:”87”},”uris”:[“http://www.mendeley.com/documents/?uuid=cc899d15-196c-4aaf-b949-b4f6c3429187”]}],”mendel ey”:{“formattedCitation”:”(Young and Isbell, 1991, Hierarchical foraging by giraffe in a heterogeneous savannah (Mahenya *et al.*, 2016), However, assessment of their health condition has not been conducted which is also the important issue to address in any protected area to different species. Since the giraffe population in Arusha National Park is decreasing, health factors may be among the issues that cause their number to decrease so this assessment is important to be conducted.

The observational health assessment of giraffes in Arusha National Park is expected to offer a good understanding of giraffes in Arusha National Park, meanwhile, this survey will highlight important aspects of giraffe conservation in Arusha Park. Furthermore, diseases and their impact on the survival of giraffes will be assessed, so as to support its conservation and management in the park.

General objective

This study aims at assessing Giraffe's general health condition in the Arusha National Park (ANAPA)

Specific objectives

i. To assess the physical body health condition of giraffes in Arusha National Park.
ii. To assess the level of gastrointestinal parasite infestation in sampled giraffes.

Research questions

i. What is the general physical health appearance of giraffes in Arusha National Park?
ii. Is there a difference in the level of gastrointestinal parasite infestation in selected giraffes?

MATERIALS AND METHODS

Research approach

This study used a mixed research approach both qualitative and quantitative research was used to address the research questions. A qualitative research approach was used in the physical assessment of the giraffes while a quantitative approach was used in assessing the level of gastrointestinal parasites eggs.

The research designs

Descriptive research was used in assessment of the physical health condition of the observed giraffes and assessment of the level of gastrointestinal parasites in the laboratory to identify eggs which affect the health condition of giraffes in Arusha National Park.

Study location

The study was conducted in Arusha National Park (ANAPA) with a coverage area of about 552km square (Winkle and Kramer, 2013) located at 3°15′ S and 37°00′ E in the Arusha region of Tanzania (Ojija. and Manyanza, 2021). ANAPA consists of two rainy seasons of which the short rains start from November to December and the long rains start from February to June (Martinol *et al.*, 2006). Rainfall on the lakes is about 1000mm per year while other areas in the park receive about 250 to 500 mm per year (Martinoli, Preatoni and Fernandes, 2006). The park consists of diversity of natural resources including plants and animals. Among animals found in the park include giraffes, Cape buffalo, zebra, warthog, the black-and-white colobus monkey, the blue monkey, flamingo, elephant, and leopard (Melubo and Jensen, 2020). There is a variety of habitats in the park which include lakes, swamps, grasslands, bush, forests, heath, and rock precipices(Lee *et al.*, 2023). This location was chosen for this study due to the fact the study of the health condition of giraffes has not been done in the area and their population is seen to decrease.

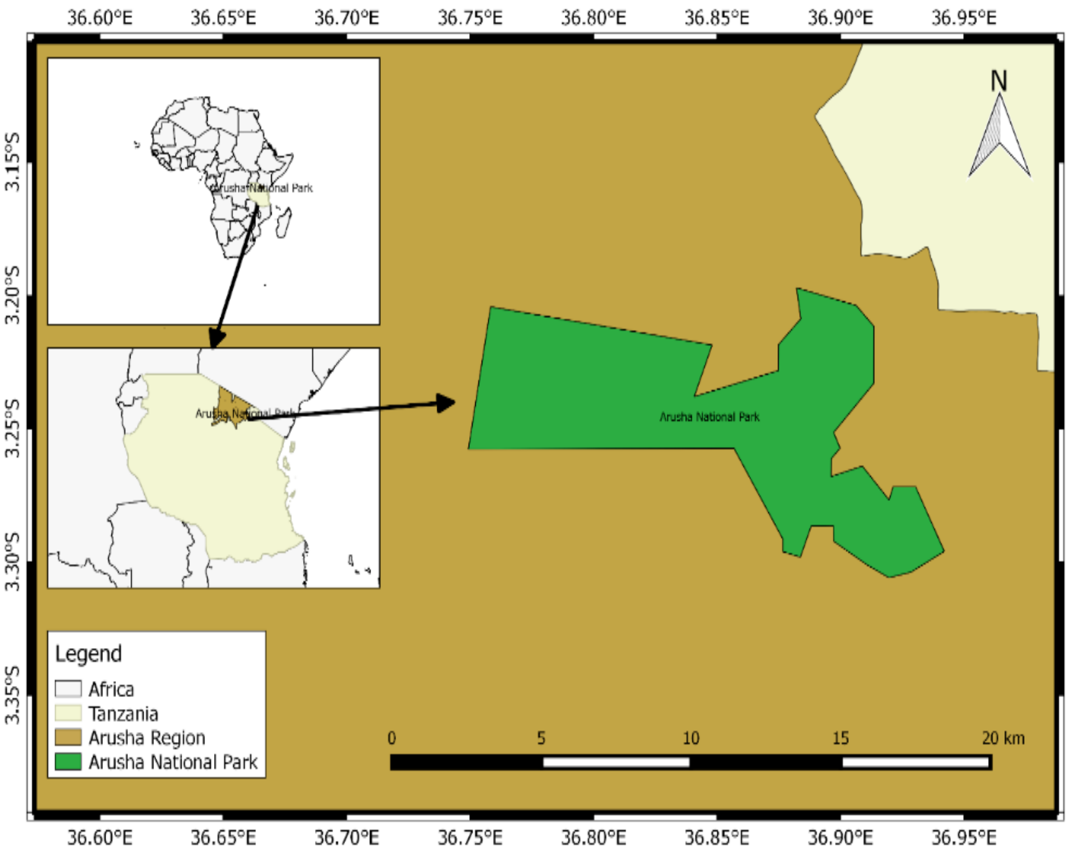

Figure 1. A map of Arusha National Park

Sampling techniques and procedures

The study used simple random sampling technique and clustered or area sampling during the faecal collection process in which each individual was having an equal chance for its pellets to be collected after defecation. Furthermore, clustered or area sampling was used to select areas in which there would be a high probability of encountering giraffe species and obtain data at a given time. Since Arusha National Park is large with 552km square, the area was subdivided into different clusters and only two clusters were selected where data collection process took place. Two clusters that were chosen included the area from Ngongongare gate to Nasula gate and the area from Momela gate to Momela Lakes.

Data collection techniques and tools

Non - invasive data collection techniques were used to collect information on the health of giraffes through direct observation and faecal sampling. Health factors may be among the causes of giraffe herd population decrease in the area. This was achieved immediately after a vehicle was stopped and waited for about 30-35 minutes then careful observation of each individual in a group by using a powerful binocular was done followed by recording their physical features, age, and sex then direct observation to assess the physical health condition of giraffe was conducted through observation of features such as ribcage, tail outlook, ribs, ischium and lumber vertebrae, buttocks, skin, swellings, hooves condition, and wounds. The researcher waited until she observed individuals in group defecated and the pellets were collected in 20 ml vials containing 10% buffered formalin solution. Samples were temporally stored in a cool box before being shipped to the laboratory.

Collected samples were processed and analysed at Veterinary Science and Wildlife Laboratories Unit, Tanzania Wildlife Research Institute (TAWIRI). The study used formol ether sedimentation technique during faecal sample processing (Suwansaksri *et al.*, 2002). A pipette was used to take about 4ml of formal saline and put it into the centrifuge tube followed by the addition of 1g faecal sample stirred with the applicator stick. The stirred solution was filtered using gauze into the cup to remove unwanted debris. The filtered solution was poured into a new clean centrifuge tube followed by the addition of 4ml formal saline and 3ml of ether then the tube was closed with a stopper and the mixture was shaken well. The centrifuge tube was placed into a centrifuge machine and the centrifugation process occurred. After centrifugation, the supernant was removed leaving the sediment in the tube. A pipette was used to obtain the sediment to place it on the glass slide then observed under the microscope to assess the parasite eggs. These procedures were applied in all 25 faecal samples collected from the study area.

An assessment tool for the faecal sampling process consisted of sample number, sex and age of the giraffe to whom the sample was collected, the total number of eggs in each sample, and egg species name observed under the microscope.

Tools used during this study were centrifuge tubes, a centrifuge machine, a highly visible binocular, Notebook and pencil, Sample collection vials, Laboratory reagents (10 percent buffered formalin, Ethyl acetate, and Distilled water), Glass slide, pipette, Cotton gauze, cups, four-wheeled vehicle, Microscope, gloves, weighing balance, measuring cylinder, beaker, cool box, dropper and microscope slide.

Data analysis

Data collected from the observation method and faecal sampling method were entered into a Microsoft Excel Spreadsheet and analysed by R- studio version 4.0.3 then displayed in tables. Descriptive analysis was used in qualitative data to analyse the physical features of giraffes which were ribcage, ribs, tail outlook, ischium and lumber vertebrae, buttocks, skin, hooves condition, swellings, and wounds while repeated ANOVA was used to examine the differences in mean level of the endoparasite's eggs identified from the laboratory sampling process. The statistical significance was set at $p<0.05$.

RESULTS

Age and sex of the giraffes observed

The age of the giraffes was categorized into two group's adult group and the young group where the total adult group was 122 (79.2%) and the young group was 32 (21.8%) whereby the female giraffes were 113 (73%) and the male giraffes were 41 (27%)

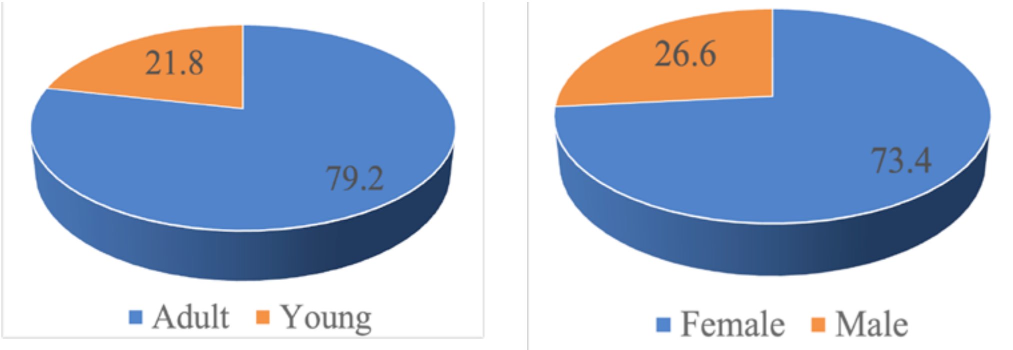

Figure 2. A pie chart showing the age and sex categories of the giraffes observed

Physical body health condition assessment of giraffes

In this objective of assessing the body health condition of giraffes physically, the results show that observed features or variables from a total of 154 giraffes were recorded into two groups. The first group was indicated by the GOOD or BAD sign for ribcage, tail outlook, ribs, ischium and lumber vertebrae, buttocks, skin, and hooves condition while others were put into YES and NO categories for swellings and wounds.

Of the ribcage observed from all giraffe species encountered, 84.4% had good condition while 15.6% had bad condition. 87% tail outlook was good while 12% was in bad condition. 87.7% of ribs were in good condition while 12.3% were in bad condition. Ischium and lumber vertebrae from all giraffes observe, 90.3% were good while 9.7% were bad. Buttocks had 92.9% good with 7.1% bad. Of the skin of all giraffes observed, 92.2% had good skin while 7.8% had bad skin. 87% hooves' condition was seen to be good while 13.3% was seen to be in a bad condition. Swellings were observed in few giraffes of which 96.8% had no swellings while 3.2% had swellings. Wounds were also observed in some giraffes, 80% had no wounds while 11% had wounds. In general, physical health conditions had 89.7% while unhealthy conditions had 10.2%

Figure 3. Showing swelling and wounds**.**

The level of gastrointestinal parasite infestation in sampled giraffes

Different gastrointestinal parasite eggs were obtained from 25 faecal samples taken from different giraffes belongs to phylum Nematoda. *Strongyloides* eggs were 27.8% (n=17), *Ternidens* 18.0% (n=11), *Trichuris* 13.1% (n=8), *Trichostrongylus* 24.6% (n=15), *Molineus* 11.5% (n=7) and unknown eggs which were unable to be identified or *unknown* eggs 4.92% (n=3) were observed in the laboratory under a microscope. *Strongyloides sp* are known by their name as Threadworms found in the small intestines, *Trichostrongylus sp* is known as Roundworms found in large intestines, *Trichuris sp* are known as Whipworms found in the caecum and colon, *Ternidens sp* are known as Hookworms found in the stomach and *Molineus sp* are found in small intestine.

Table 1. Showing the number and percentage of gastrointestinal eggs

SPECIE EGG NAME	PERCENTAGE	TOTAL NUMBER
Strongyloides sp	27.80%	17
Ternidens sp	18.00%	11
Trichuris sp	13.10%	8
Trichostrongylus sp	24.6%	15
Unknown egg sp	4.90%	3
Molineus sp	11.50%	7

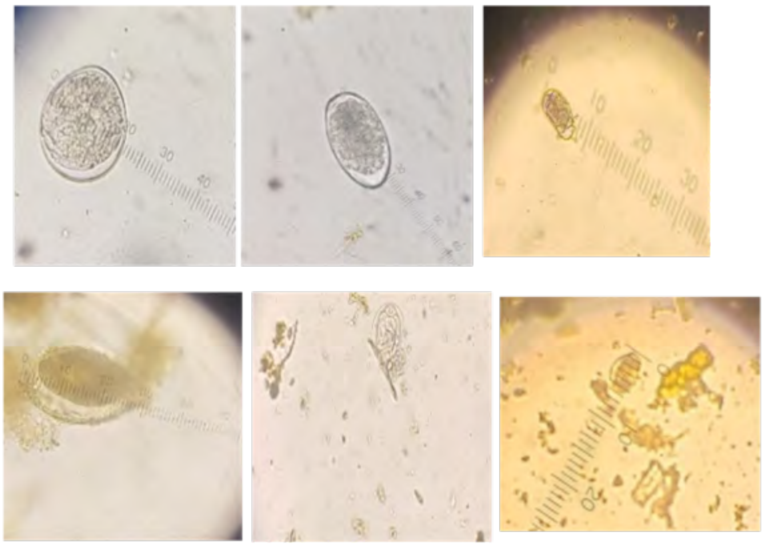

Figure 4. Showing gastrointestinal parasitic eggs identified from faecal samples.

Sample names	Mean difference	P values
Strongyloides sp. Egg - Molineus sp. Egg	-0.666666	0.978
Ternidens sp. Egg - Molineus sp. Egg	-1.300000	0.756
Trichostrongylus sp - Molineus sp. Egg	1.166666	0.871
Trichuris sp. Egg - Molineus sp. Egg	-1.500000	0.668
Unknown sp. egg - Molineus sp. Egg	-2.000000	0.531
Ternidens sp. Egg - Strongyloides sp. Egg	-0.6333333	0.939
Trichostrongylus sp - Strongyloides sp. Egg	1.8333333	0.270
Trichuris sp. Egg - Strongyloides sp. Egg	-0.8333333	0.866
Unknown sp. egg - Strongyloides sp. Egg	-1.3333333	0.717
Trichostrongylus sp - Ternidens sp. Egg	2.4666667	0.086
Trichuris sp. Egg - Ternidens sp. Egg	-0.2000000	0.999
Unknown sp. egg - Ternidens sp. Eg	-0.7000000	0.975
Trichuris sp. Egg - Trichostrongylus sp	-2.6666667	0.072
Unknown sp. egg - Trichostrongylus sp	-3.1666667	0.0748
Unknown sp. egg - Trichuris sp. Egg	-0.5000000	0.995

Table 2: Multiple comparison table showing the level of gastrointestinal parasite eggs.

Turkey multiple comparisons for repeated ANOVA was used to calculate the p-value from the mean differences obtained (Df = 5, Sum Sq = 19.06, Mean Sq = 3.813, F value = 2.864, P = 0.0494) The p-value obtained was 0.0494 less than the significance level of 0.05 hence this accepts the research question that there is a difference in gastrointestinal infestation in sampled giraffes causing their health depression. So, this indicates that there is a relationship between the giraffe population and their health in Arusha National Park.

DISCUSSION

During direct observation, the results show that female giraffe’s number higher than males giraffe number due to the reason that a small number of males in a group reduce competition, especially during mating hence for that reason each male giraffe in a group has an equal chance to mate with the female hence decreasing competition (Young and Isbell, 1991)with open vegetation having female-biased groups, and tall, thick vegetation having male-biased groups. On a ranch in south-central Kenya, we quantified habitat differences of male and female giraffe groups and showed that the preference for open habitats by female groups was limited to groups with young. We suggest that this difference is due to the avoidance of predators of young giraffes. We also showed that rates of giraffe feeding peaked at intermediate feeding heights equal to approximately 60% of adult giraffe height. In the dense habitats with a variety of tree heights used by male groups and female groups without young, both male and female giraffes fed most at heights where they could feed fastest. However, in the open habitats used by female groups with young, females fed mostly at heights below optimum because these habitats are dominated by short food plants. On the other hand, the dominant males accompanying these female groups fed at heights above optimum on rare tall trees, possibly to increase intrasexual vigilance. Apparently, both male and female giraffes sometimes forfeit feeding efficiency tor short-term reproductive gains. 1991 Blackwell Verlag GmbH”,”author”:[{“dropping-particle”:””,”family”:”Young”,”given”:”Truman P.”,”non-dropping-particle”:””,”parse-names”: false,”suffix”:””},{“dropping-particle”:””,”fami ly”:”Isbell”,”given”:”Lynne A.”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:”” }],”container-title”:”Ethology”,”id”:”ITEM-1”,”issue”:”1-2”,”issued”:{“date-parts”:-[[“1991”]]},”page”:”79-89”,”title”:”Sex Differences in Giraffe Feeding Ecology: Energetic and Social Constraints”,”type”:”article-jou rnal”,”volume”:”87”},”uris”:[“http://www.mendeley.com/documents/?uuid=cc899d15-196c-4aaf-b949-b4f6c3429187”]}],”men deley”:{“formattedCitation”:”(Young and Isbell, 1991. Also, Sexual segregation in many ungulates has been reported which causes an unequal number of males and females in their groups (Marealle, Holmern and Røskaft, 2020). Male giraffes are mostly solitary from the groups because they are always searching for oestrous females (Marealle, Holmern and Røskaft, 2020) hence this shows why females are many in a group of giraffes compared to males .

Adult giraffes have been observed to be higher in number compared to young ones this might be because of increasing vigilant in the group from predation since most of predators always capture the young ones in a group. Hence a large number of adults in a group increase protection to young ones. (Marealle, Holmern and Røskaft, 2020) said that vigilant is high when the proportion of adult female is higher in a group to protect the calves or young ones from predation while adult male giraffes are less vigilant since most of the time male giraffes focus on mating opportunities. Protection in a group is higher when adults are many compared to young ones.

Based on the external condition of the giraffes observed in Arusha National Park, physical features indicated that they were healthy since their external appearance healthy percentage exceeded the percentage of unhealthy. (Clavadetscher *et al.*, 2021) reported that ribs were not considered a practical feature for the body condition scoring of giraffes due to the presence of large skin which obscure visibility. Large mammals consist of thick skin which may obscure the visibility of other physical features during health assessment (Kido *et al.*, 2018) hence when assessing the animal health basing on its physical appearance the correct answers may not be obtained. A large mammal may appear healthier physically but it may be unhealth when assessed through laboratory diagnosis (Washabau et al., 2010).

Though their physical appearance was seen to be healthier, some giraffes had wounds and swellings which might be caused by endoparasites' infestation or other ecological factors and human factors. *Strongyloides sp* were the most species detected. This nematode specie is believed to cover about 50% of the gastrointestinal parasite species and infect a large number of mammals, reptiles, birds, and amphibians (Camber, 2020). Not only wildlife species but also the nematode affects large number of people worldwide. According to World Health Organization (WHO) 30-100 million people are infected with *Strongyloides sp* (Camber, 2020). This specie can survive a variety of environmental conditions such as high temperature, humidity and other extreme conditions such as drought and frost (Boyko, Volovyk and Shendryk, 2022). They survive for a long time by attaching themselves in the plant roots and the soil. *Strongyloides sp* causes strongyloidiasis after they are attached to the mucous membrane of the small intestine of many ruminants including giraffes hence causing illness to the animals (Boyko, Volovyk and Shendryk, 2022). Hence giraffes in Arusha National Park are also affected by this gastrointestinal parasite which is not good for their well-being.

Trichostrongylus sp was the second parasitic egg which was detected three times higher than *Ternidens sp*, *Molineus* sp and *Trichuris sp*. similar study was done by (Park et al., 2008) and found that this parasite is common to many ruminants, so this kind of parasite is likely to be found in any ruminant animal in the wild including giraffes. This endoparasite can survive in dry condition and causes trichostrongylidosis which leads to poor body condition of different ruminant wild animals including giraffes (Vanderwaal et al., 2014)

Ternidens sp and *Molineus sp* was also found in giraffes assessed in Arusha National park though these parasites are common in primates such as monkeys, gorillas and baboons (Gillespie, 2006), they can be transmitted to other animals in the wild by sharing water sources and food materials. Giraffes are affected by these parasites mostly through water sources compared to forage materials since they forage from plants of higher height hence water source is the main transmission of these endoparasites from same water sources in the wild (Vanderwaal et al., 2016).

Trichuris sp were also detected to impact giraffes in Arusha National Park but they occurred in a small amount. *Trichuris* in giraffe is a consistent gastrointestinal finding worldwide (Shusterman *et al.*, 2021). Trichuris has many problems when they invade any animal, firstly they cause low fecundity to animals, diarrhea, weight loss, decreased appetite and mortality (Shusterman *et al*., 2021). This is why Fowler's Zoo and Wild Animal Medicine Volume 8, insists that treatment of Trichuris should be done immediately even when only a few eggs are found on a faecal sample of an animal examined.

Unknown endoparasites eggs which were unable to be identified were also found during faecal sampling which also play a part in giraffe health depression in the park.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Regardless of physical well-being of giraffes in the park, gastrointestinal parasites play a greater role in giraffe health. Increased in helminths infestation in giraffe might be linked to increased interaction between livestock, humans and wild animals. Arusha National Park is highly encroached with communities which practice different illegal activities in the park such as grazing. The transmission of these parasites interferes with the health condition of wild animals including giraffes. Also, habitat loss and land use changes has caused giraffe species to move from the park to people's settlement of which the interaction leads to transmission of different gastrointestinal parasites from pasture and environment.

Recommendations

Regular monitoring and treatment programs, regular health assessment in Arusha National Park giraffes including faecal examinations and veterinary check-ups will help to detect and treat parasitic infections at their early stages. Also, habitat management with in the park should be ensured to restore and regenerate habitats that support giraffe. Collaboration and research between wildlife researchers, veterinarians and park authority should be strengthened since through this collaboration, dealing with gastrointestinal parasites with in the park will be easily. Provision of education and involvement of local communities in conservation, since some parasites are passed to giraffes from livestock when illegal grazing with in the park is done, local communities should be given education about conservation and this can help to reduce the burden of gastrointestinal parasites affecting giraffes.

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STATUS AND COMMUNITY CONTROL MEASURES OF HUMAN-BAT CONFLICT IN DAR ES SALAAM CITY COUNCIL, TANZANIA

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ABSTRACT

This study was conducted to determine the status and community control measures of human-bats in Dar es Salaam City Council (DCC). The study was conducted at Kivukoni, Upanga East and Upanga West wards of the Dar es Salaam City Council. The study was also conducted at Sea Cliff Hotel and Slipway Hotel in Kinondoni Municipality as well as at Kigamboni where bat problems were also reported. The overall objective of the study was to determine the status and impacts of bats in Dar es Salaam City Council and propose rational and sustainable control measures. Methods used during the survey were Key Informant Interviews (KII), inspection of bat roosting trees, inspection of buildings and other structures, inspection of bat droppings and bat noises, inspection of caves and other underground structures, and netting of bats for bat identification. Results showed that community members had a negative attitude on bats due to their associated impact like droppings, noises and mess, property damage especially coconut trees and potential public health risks as they might carry zoonotic pathogens. The survey noted that households and community members were using a number of bat control measures including use of noises, beating tins or corrugated iron sheets placed on trees, use of bells, use of mist nets, use of spot lights, pruning or cutting of bat roosting trees. The survey recorded three bat species namely straw-coloured fruit bat (*Eidolon helvum*), Egyptian fruit bat or Egyptian rousette (*Rousettus aegyptiacus*) and small brown insectivorous bat (*Myotis spp*). The most common roosting areas for bats in Dar es Salaam City Council were trees; and that there were no bats found inside a house except for one unfinished building in the City Council. Trees used by bats were *Leucaena spp*, *Azadirachta spp*, *Mangifera indica* (Mango tree), *Adansonia digitata* (Baobab), *Moringa oreifera,* coconut tree, palm, *Saraca asoca* (asoca tree), Pinus spp (pine), Tamarindus spp Tamarind), *Terminalia spp*, *Terminalia catappa*, Indian plum, *Araucaria columnaris* (Cook pine), and *Trichilia emetica.* The most common drivers of bat presence in the affected areas were presence of urban back yards with plentiful roosting trees; habitat change/ loss outside Dar es Salaam due to increased human population coupled with human settlement, infrastructure development, poor tree management especially pruning, tall trees and large canopy. It was concluded that human-bat conflict in Dar es Salaam City Council is very high due to availability of roosting sites, abandoned buildings, poor tree management and poor environmental conditions of some homesteads. Control measures should be directed towards community awareness creation on living with bats or human-bat coexistence because complete bat control or eradication is not possible.

Key words: bats, Egyptian fruit bat, human-bat conflict, straw-coloured fruit bat

INTRODUCTION

Bats are mammals of the order Chiroptera, the second most diverse or largest order of mammals (Rego et al., 2015). Bats have been on earth for more than 50 million years and it is estimated that there are more than 1,400 species worldwide; and widely dispersed across the six continents. Bats are the only true flying mammals, they are warm-blooded, give birth and suckle their young, long-lived (over 20 years), intelligent and have a complex social life. Bats play a great role in tropical ecosystems including seed dispersal, pollination, forest regeneration, control of arthropod populations, and high quality bioindicators (Sato et al., 2008; Steven et al., 2013; Meyer et al., 2010). Through pest consumption, insect-eating or insectivorous bats can eat on average of half or 100% of their body weight of insects in each night. The consumption of pests or arthropods by bats results into reducing crop damage and disease-causing vectors, resulting into reduced need for use of insecticides. On the other hand, nectar-feeding bats that drink the sweet nectar inside flowers pick up dusting of pollen and move between flowers as they feed, resulting into enhanced pollination services. Moreover, fruit-eating bats drop seeds back to ground through their droppings and therefore enhancing pollination services. Tanzania has more than 31 species of the bats. Generally, bats eat insects and other invertebrates while others eat fruits.

Many bat species share space with people and domestic animals (Jackson et al., 2024). Bats have roosting sites, hibernation sites, maternity sites, mating sites and swarming sites. The bats tend to switch roosts due to temperature variation, predator presence, avoidance of parasites, vicinity to foraging areas, and introduction of juveniles to the network. Bats are often considered harmful, dangerous and carry diseases (Rego et al., 2015). Bats are increasingly being recognized as hosts for pathogens that affect humans (Messenger et al., 2003). In Tanzania, bats have been recognized to carry zoonotic pathogens including corona, paramyxo virus and beta-coronaviruses (Kazwala et al., 2019).

Increasing human population, habitat transformation, climate change and urbanization have considerably increased human-bat interaction, resulting into various forms of conflicts. The Tanzania Wildlife Research Institute was required by the Ministry of Natural Resources and Tourism (MNRT) to investigate a problem of increased population of bats in Dar es Salaam City Council. Specifically, the bat associated issues raised were increased noise pollution, offensive smell due to bat urine; and bat droppings on buildings, open gardens, vehicles and home grounds. Therefore, this study was conducted to determine the status and impacts of human-bat conflict in Dar es Salaam City Council and propose rational and sustainable control measures. Specific objectives of the study were to determine community knowledge, attitude and practices related to bats; to determine species composition, distribution, and abundance of bats in Dar es Salaam City Council; to determine bats control measures used by people in Dar es Salaam City Council; and lastly to recommend rational and sustainable human-bat conflict control measures in Dar es Salaam City Council.

MATERIALS AND METHODS

Study areas

The study was conducted in Dar es Salaam City Council in three wards namely Kivukoni, Upanga East and Upanga West. Streets/ areas involved in Kivukoni ward were Sea view, Baraka Obama, Luhinda, and Alli Hassan Mwinyi Road where the survey was conducted at 27 inspection sites. Streets/ areas where the study was conducted in Upanga East ward was Kitonga, Lugalo, Magole, and Jamatin where the survey was conducted at 8 inspection sites. Street where the survey was conducted in Upanga West ward were Mindu, Budha temple, and Selander bridge where the survey was conducted at 2 inspection sites. In addition, the survey was conducted in areas close to Slipway Hotel in Kinondoni Municipality, Sea Cliff Hotel in Kinondoni Municipality and one location in Kigamboni area in Temeke Municipality where complaints of human-bat conflict were also reported during the survey.

Methods

The study used a combination of methods namely desk review, Key Informant Interviews (KII), Inspection of buildings and other structures, Inspection of trees and Netting to capture bats for identification. Desk review and consultation with Local authorities was used to get background information on recent bat sightings and an indication of status and distribution of bats in the area. Key Informant Interviews were used to obtain important historical information about the presence, trend and dynamics of bats in the localities. Local authority leaders, elders and community members in each area were interviewed during the study regarding bats presence, associated problems and applied control measures. Inspection of buildings and other structures was used to detect bat species that roost in abandoned buildings or structures, or roost under roofs of buildings in general. Inspection of buildings aimed to find evidences for the presence of bats in buildings and other structures. Presence of bat droppings and oil, bones, feathers, feeding remains, and/or bat noises were used to indicate bat presence. Inspection of trees was used for the purpose of searching fruit bats that roost on trees; especially stems, branches, leaves, and cavities/ crevices using binoculars and cameras. Netting of bats using mist nets was used to capture bats in each area for identification purposes. Inspection of caves and underground structures, buildings due to demolition, alteration, repair or development was also conducted. Visiting all of these areas and searching for bat signs during the survey was important for identifying various species present in Dar es Salaam City Council.

RESULTS

Community knowledge, attitudes and practices on bats

The survey showed that all (100%) respondents in the study areas knew bats and were aware on the presence of bats in their area and other areas, Dar es Salaam City Council as well as areas outside Dar es Salaam City Council. Most (98%) community members had a negative attitude on bats due to their associated impacts like bat droppings, noises, property damage especially coconut trees and potential public health risks as they might carry zoonotic pathogens. Bat problem in some areas appeared to be a recent phenomenon of about 6 months to 5 years ago. Some community members said that bats were few some years back, were seen on and off in some areas, and that it was an increasing nuisance. One Key informant said that Sea view area was a Germany Botanical Garden and had bats since the Germany era, therefore it might be historically a bat area. Some respondents who grew up at Lugalo in Upanga East said that they had grown with bats in their areas and they had no problem with bats, and that newcomers are the one not used to bats. Participant observation during the survey showed that community members were using a number of bat control measures including making noises, beating tins or corrugated iron sheets placed on trees, use of normal and electric bells, use of mist nets, use of spot lights, tree pruning and cutting of bat roosting trees. In-depth interview with key informants on the effectiveness of these community control measures showed that some of these measures have been used/ habituated to bats and that bats return to the roosting trees few minutes after they have been displaced by the deterrent method.

Species composition, distribution and abundance of bats

The survey recorded three bat species namely straw-coloured fruit bat (*Eidolon helvum*), Egyptian fruit bat or Egyptian rousette (*Rousettus aegyptiacus*) and small brown insectivorous bat (*Myotis spp*). Straw-coloured fruit bats were the commonest species at Kivukoni, Upanga East and Upanga west; which had the highest density and bat associated problems. Egyptian fruit bats (*Rousettus aegyptiacus*) were found only at an unfinished/ abondoned building whose construction stopped in 2011, located near Muhimbili National Hospital (MNH) and also at a cave near Sea Cliff Hotel along the shore of the Indian ocean. Small brown insectivorous bats (*Myotis spp*) were found only in Kigamboni Municipality, both in caves and at a health facility building (dispensary). The most common roosting area for bats was trees, bats found roosting in a house was only at two paces namely a health facility in Kigamboni and the abandoned building near Muhimbili National Hospital.

Bat ecology and roosting trees in the area

The survey showed that a single colony was found on most roosting trees (92.8%), and some colonies had over 800 bats. Most of the Straw-coloured fruit bats were found to roost on trees at a height of about 5 meters or higher. Bats appeared to roost in almost all trees found in the area, the common tree species used for roosting were *Leucaena spp*, *Azadirachta spp*, *Mangifera indica* (Mango tree), *Adansonia digitata* (Baobab), *Moringa oreifera,* coconut tree, palm, asoca tree (*Saraca asoca*), pine tree (Pinus spp), Tamarind tree (Tamarindus spp), Terminalia spp, *Terminalia catappa*, Indian plum, cook pine (*Araucaria columnaris*), and *Trichilia emetica. Kyaya nyasica* trees were perceived as less used for roosting. Observation showed that bats left roosting trees from 6pm for foraging and returned early in the morning to their rooting sites from 5am. In-depth interview conducted with people failed to determine the foraging sites for bats. Key informants said that peak population of bats in the area was seasonal, with most bats leaving the roosting sites in in Dar es Salaam City Council in April (though few remain) and return or come back those areas from July, and it was not known where do bats go in that period.

Drivers of bats presence

The study recorded a number of factors that might be the causes of bats presence in Dar es Salam City Council especially fragmentation and loss of native forests in and near Dar es Salaam. Due to increase in human population with associated demand for land for settlement and subsistence/ urban agriculture, many native forests have been lost in the city council. As a result, the few trees that have been planted or left had become the only roosting sites for bats in the area. Other drivers include presence of urban back yards with plentiful roosting trees that have been planted around households. Many places or households where bats were found had plentiful tree backyards, which were good habitats for bat roosting; habitat change and loss outside Dar es Salaam due to increased human population coupled with human settlement, infrastructure development. Habitat change due to infrastructure development in Dar es Salaam City Council like roads and railways have exacerbated habitat fragmentation, thus affecting the majority of bat roosting sites. Also, another driver was poor tree management especially pruning, tall trees and canopy. Most of households or areas that had bats were characterized by presence of trees that were poorly managed especially lack of tree pruning as well as general backyard tree management. In this case, most trees were tall enough and with good canopy to attract bats; poor environmental hygiene especially grown hedges or live fences (trees). Most of areas that had bats were characterized by poor environmental hygiene especially poor management of live fences or hedges. This exacerbated poor tree management as a driver of bats presence in the area. Another driver was presence of abandoned buildings and poorly managed compounds. Some of the areas with abandoned buildings were the previous Slovenian along Alli Hassan Mwinyi road and the previous Romanian Embassy building along Sea view road. Buildings whose construction activities stopped for a long time were also a main source of bat roosting or hiding places.

Community awareness creation on living with bats

Due to the fact that complete control or elimination of bats in an area sometimes might be very complicated due to various factors; community awareness creation on living with bats or human-bat coexistence without adverse impacts on public health should be advocated. The following is a list of the 'to do' and 'not to do' in advocating human-bat coexistence as well as to safeguard public health in an area. They include do not touch or handle a bat to avoid risk of diseases, do not put yourself in position where a bat can bite or scratch you, bring in your washings at night, park your car under shelter or car shade to avoid bat droppings, avoid disturbing roosts as when stressed they can shed pathogens, net fruit trees and apply complete netting, plant roost trees away from homes, plan ahead to manage bats arrival season, and last but not list plant trees that are not preferred by bats for roosting.

CONCLUSIONS AND RECOMMENDATIONS

Bats problem and human-bat conflict in Dar es Salaam City Council is very high due to availability of plenty roosting sites, abandoned buildings, poor tree management and poor environmental conditions of some homesteads. Control measures should be directed at reducing the bat population through use of various mitigation measures including selective tree pruning, regular insecticidal spraying of roosting sites to maintain drug residues, complete netting of trees and the use bat repellents in some of the critical bat roosting areas.

In order to achieve effective control, a campaign and large area approach is advised for every chosen control measure, so that the same intervention is used at the same time at each street/ ward/ area in order to achieve a wide impact. When a control approach is done on a small scale (e.g. one street or area), its overall effect will be low due to bats flying and moving to other areas where the intervention is not being applied and later coming back to the area after the intervention. In this case, resources should be mobilized jointly to implement a bat control operation that should be done at the same time in the Dar es Salaam City Council where bats are a problem as well as in other Municipalities (Kinondoni, Kigamboni) with bat problems. If selective pruning or tree removal will be the choses method, this should be done when bats have left to breeding sites during their seasonal migration, and that tree removal should be followed by planting of other trees that are not preferred by bats. Tree pruning should be done where it is very necessary and with great care due to its environmental consequences on tree removal/ cutting, and should be done subject to securing a permit from the City Council.

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TRADITIONAL BEEKEEPING PRACTICES AND THEIR EFFECTS ON COMMUNITY-MANAGED FORESTS IN CENTRAL, TANZANIA

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ABSTRACT

Traditional beekeeping is one of the subsistence economic activities practised by local communities adjacent to the dry Miombo woodlands with indigenous knowledge and skills. However, the benefits gained through this activity are often linked with detrimental effects on forest ecosystems owing to its extensive use of live trees and the adoption of low-technology honey harvesting methods. The rampant rate of forest degradation due to poor beekeeping practices affects forest ecosystems adversely and reduces the beekeeping potential as an important income-generating activity. More importantly, there is a need to better understand traditional beekeeping destructive practices, particularly in community-managed forests with relatively lower protection statuses. This study investigated the use of wooded forest materials and harvesting practices in traditional beekeeping and then quantified their effects on forest, and honeybee post-harvest colony absconding. Results indicated that nearly 35% of total destructive impacts on the forest ecosystem were due to traditional beekeeping practices. Besides, inappropriate honey harvesting methods caused the absconding of bee colonies in 51% of all visited hives. A forest management plan coupled with effective management actions should be adopted to sustainably utilize forest resources and allow for the proper functioning of life-enabling ecological processes.

Keywords: Bee colony, forest degradation, forest ecosystem, miombo forest, traditional beehive

INTRODUCTION

Forest reserves are well known for their enormous contribution to economic development and biodiversity conservation in Tanzania (Augustino et al. 2016). Rural and marginalized communities living around forest reserves greatly depend on timber and non-timber forest products to sustain their living (Agera 2011; Lalika 2008). A vast number of animals find their home and acquire all life necessities in forests. The existence of a variety of plant species in a healthy and connected forest enables the ecosystem to absorb environmental changes and thus ensuring the provision of ecosystem goods and services upon demands (Campbell et al. 2007; Naeemet al. 1995; Naeem 1998).

Forest reserves in Tanzania are basically made up of two categories; natural forests and plantations (URT 1998). Natural forest ecosystems in west Tanzania are renowned for being rich in dry Miombo woodlands predominantly made up of plants of the genus Brachystegia*,* and *Julbernardia* (URT 1998). Dry Miombo woodlands provide not only timber products but also support non-timber products such as honey produced through beekeeping activities by local communities bordering forest reserves. The presence of melliferous plants such as *Brachystegia speciformis, Brachystegia boehmii,* and *Julbernadia globiflora* guarantees bees with pollens and nectars for honey production (Campbell et al. 2007).

The beekeeping industry has recently marked rapid growth while serving as an important income-generating activity for the majority of communities residing adjacent to Miombo forests in Tanzania (Famuyide et al. 2014; Wagner et al. 2019). Concurrently, there exists an increasing demand for bee products in local and international markets (Hausser and Mpuya, 2004; URT 1998). The current drive for beekeeping is based on the fact that it is an environmentally friendly activity providing local communities with alternative sources of income as well as ensuring sustainable conservation of the country's biome (Agera 2011; Lalika 2008). Despite the socio-economic and ecological benefits of beekeeping in Tanzania, beekeepers still use traditional beehives which are believed to cause forest destruction, particularly in dry Miombo woodlands of western Tanzania (Beyene and Verschuur 2014; Kubojaet al. 2021).

Most of the small-scale beekeepers in west Miombo of Tanzania engage in traditional beekeeping practices that make use of the wooded materials from the ecosystem through the utilization of locally available woody plants in constructing bark and log hives (Fischer 1993). The widespread and extensive use of bark and log beehives for beekeeping by the local communities is based on the fact that they are portable (less heavy), and cheaply constructed and less expensive hence requiring less capital and time investment. While constructing bark and log beehives, a large number of flowering tree species are cut or de-barked to death thus decreasing forest tree abundance and richness (URT 1998). Nevertheless, hollow trees particularly those with stingless bees are cut down by beekeepers in search of honey. Traditional beekeeping practices and honey hunting are the two activities if overlooked may pose important threats to the forest ecosystem (Okoye 1999).

The possible effects of traditional beekeeping include biodiversity loss due to heavy harvesting beyond the regeneration rate of specific species such as *Brachystegia* species with interwoven fiber patterns (Mickels-Kokwe2006). Nectariferous plant species are particularly under immense pressure as they're de-barked for hive construction which in turn affects the beekeeping industry in the long run (Mickels-Kokwe 2006). In the process, the majority of trees are merely damaged impending the growth rate and making trees susceptible to pests and diseases. Traditional beekeeping also uses heavy smoke resulting in accidental ignition of fire harming tree regeneration (Clauss 1991; Mickels-Kokwe 2006). Some studies have tried to assess the impact of traditional beekeeping and how it improves the social and economic well-being of mankind (Wiersum 2000; Campbell et al. 2007; Augustino et al. 2016). However, less has been done to assess the destructive impacts associated with traditional beekeeping practices on forest conditions.

Another threat is posed during the harvesting period when beekeepers apply fire which in turn kills the majority of bees and subsequently destroys bee colonies or weakens their performances causing colony absconding (Kuboja et al. 2020). The honey harvesting process with traditional beehives also exploits almost everything kept as a food reserve for bees especially when beekeepers take the entire set of honeycombs leaving the colony with nothing to feed. Previous studies have reported that disturbance by predators and shortages of forage and water resources for bees are the main factors leading bees into abandoning their nests (Kuboja et al. 2020; Nurie 2020; Schneider and McNally 1992; Winston et al. 1979). But, little is known with regard to how traditional beekeeping practices contribute to absconding or reducing honeybee colonies and their consequences on the beekeeping industry.

Absconding is a non-reproductive process, where the entire colony and the queen abandon the nest to re-establishes habitation elsewhere (Nurie2020; Winston et al. 1979). Colony absconding can be of two forms; planned and forced absconding (Nurie 2020; Schneider and McNally 1992). Forced (disturbance-induced) absconding occurs as a result of disturbances induced by predation and pests, and sometimes physical environmental conditions such as fire incidences, high temperature, and leakage of water into the hive (Nurie 2020). Planned (resource-induced) absconding often occurs during the dearth period as a result of shortages of water and bee forage resources (Nurie 2020; Schneider and McNally 1992). Absconding is one of the challenging phenomena for beekeepers because the loss of bee colonies might mean a reduction in honey production and consequently low-income generation. But yet, we have little understanding of the interconnectedness between traditional beekeeping practices and colony absconding. This study investigated the use of wooded forest materials and harvesting practices in traditional beekeeping and then quantified their effects on forest conditions, and honeybee post-harvest colony absconding. We hypothesized that traditional beekeeping will contribute substantially to tree cuttings, thus affecting adversely the forest condition (Fischer 1993; Mickels-Kokwe 2006). We also predicted that inappropriate honey harvesting practices will cause the absconding of bee colonies as noted in the previous study (Kuboja et al. 2020).

MATERIALS AND METHODS

Study area

The study was conducted in the Kululu Community Forest located between the latitude 6.48°S and 6.75°S; and longitude 33.10°E and 33.70°E. The study area occupies 920.77km^2 and the village general land at the center-west part of Tanzania, in Sikonge and Manyoni Districts. The study area is part of the national wildlife corridor linking the Katavi and Ruaha National Park (Riggio and Caro 2017). Kululu CF is bordered by Rungwa River and Nyonga Forest Reserves (in the west), Rungwa Game Reserve, Kintanula, and Mwamagembe villages (in the East), Itulu Hills Forest Reserve (in the North), and the Majojoro, Mwitikio, and Kapumpa villages (in the south) as indicated in Fig.1.

The study area is covered by dry Miombo forest ecosystems providing numerous goods and services benefiting the local communities living adjacent to this community forest. The area being rich in *Brachystegia* and *Jubernadia* species ensures bees with an adequate amount of forages as well as an excellent source of nectar for honey production, thus being recognized as an important beekeeping zone in the country. The presence of shaded lands and the Kululu River which borders the Kululu CF in the north ensures the availability of surface water and cool areas throughout the year hence making it suitable bee apiary grounds for beekeeping.

The main income-generating activities stemming from the existing forest ecosystems in the study area are not limited to beekeeping, mushroom picking, wildlife tourism, and selective timber extraction. Generally, beekeeping presents an important economic activity in the area despite its production being of low quality used mainly for food, and partly commercialized at local markets. Beekeeping is practiced through local techniques and forest degrading methods which eventually harms the forest ecosystems. The expanding human population combined with the lack of effective forest resources management, boosts uncontrolled human exploitation leading to increased forest degradation from which local communities would hardly continue receiving benefits from these resources.

METHOD FOR DATA COLLECTION

Tree cutting survey

To quantify the extent to which trees are cut in traditional beekeeping practices, six parallel line transects (summing 76Km) were produced systematically from a random start at specified distance intervals (Morgan et al. 2018) of 10km apart using QGIS 2.18.12 across the Kululu CF (Fig.1). Line transects were laid in such a way that each location had an equal chance of being selected and thus cut across different habitat types, human disturbances, and elevation gradients. Before starting the transect, a distance of at least 1 km was covered to ensure that only areas with less edge effects are considered (Maijo et al. 2020).

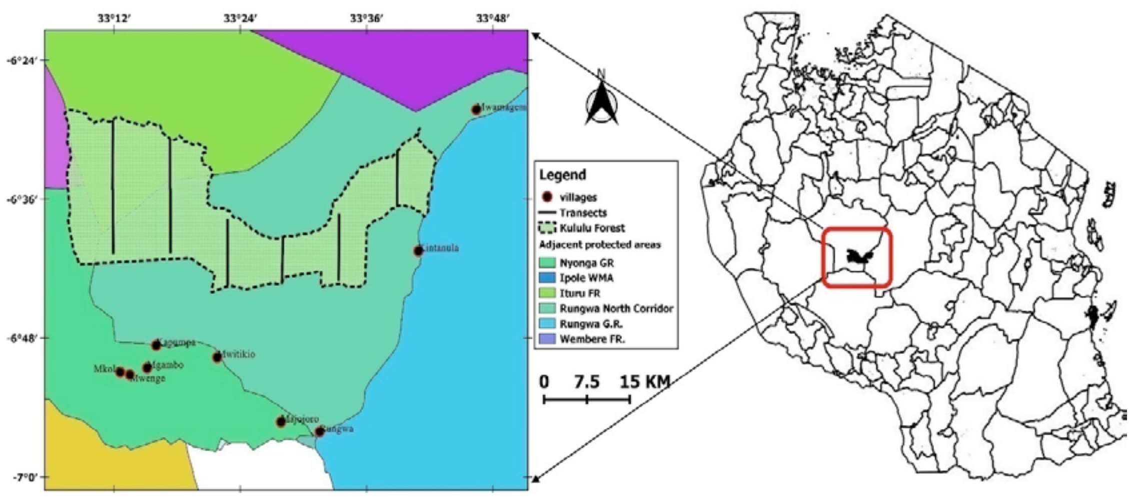

Fig.1: Position of line transects (black lines) in the study area, surrounding protected areas, and villages adjacent to the Kululu Community Forest, in 2022

Various human activities were recorded along the sampled transects based on visible signs (Maijo et al. 2020; Morgan et al. 2018; NAFORMA 2010; Struhsaker 1997). Human disturbances were recorded by two persons walking parallel to the transect each at a distance of 20 m on both sides (NAFORMA 2010). Tree cuttings for both traditional beekeeping and non-beekeeping purposes were recorded on a sampling width of 40 m (20 meters each on the left and right along the walking direction). The recorded human disturbances were categorized depending on their uses, whether being used for beekeeping or non-beekeeping purposes. While walking, signs of human activities encountered in different vegetation types along transects were identified, and GPS coordinates were marked for geographical references.

Harvesting practices

Three hundred, and ninety-seven (397) beehives were randomly selected from atleast two beekeepers from each surrounding village (Mwamagembe, Kintanula, Rungwa, Majojoro, Mwitikio, and Kapumpa). The selectedbeehives were visited for visual observations to learn how beekeepers harvest honey locally from local beehives (bark and log beehives) in the area and whether this contributes to honeybee post-harvest colony absconding. In every selected hive data on the type, vegetation types, near topographical futures, harvesting methods, estimated hanging heights, hive length, and diameter, and data on the presence of bees were recorded. Only hives that had bees prior to the honey harvesting process were considered. Seven days after harvesting, we went back to the selected hives and see if bees are still present or had absconded due to disturbance induced during the harvesting processes. GPS coordinates were taken to locate the selected hive and draw the location map.

Data analysis

Tree cutting survey

To determine the extent to which traditional beekeeping contributes to forest degradation in the Kululu CF, a summary of frequency, types, and location of recorded human activity was composed keeping in mind that each activity might have a different destructive effect on forest conditions thus assigning them to impact scores between 1 to 5, lowest to highest impacts scores (Morgan et al. 2018) correspondingly. The frequency of human disturbances evidenced was computed using signs encounter rates per kilometer walked. To measure the severity of human disturbance, the computed impact scores were multiplied by the frequencies of signs encounter rates (Morgan et al. 2018), followed by summing up an overall severity of each human disturbance for both beekeeping and non-beekeeping activities. The destructive impacts of traditional beekeeping and non-beekeeping activities on the forest ecosystem were compared based on the disturbance severity measured (Maijo et al. 2020). We anticipated that the rate of forest destruction will increase as traditional beekeeping activities intensify and thus, calculating the destructive impacts of traditional beekeeping and then comparing the severity values with non-beekeeping activities. Mann-Whitney test was used to compare tree cuttings used for traditional beekeeping and non-beekeeping purposes.

Harvesting practices

To determine the extent to which traditional beekeeping contributes to honeybee's post-harvest colony absconding, we summarized data from all observed beehives and compared hives where bees were present with those where bees absconded one week after honey harvesting. Results provided a quantification explaining the extent to which the use of traditional beehives contributes to honeybee's post-harvest colony absconding.

RESULTS AND DISCUSSION

Observed signs of human activities not related to beekeeping had a slightly different but not significantly higher encounter rate than that of traditional beekeeping ($U = 15.5$, $P > 0.05$). Observed signs for traditional beekeeping and honey hunting purposes accounted for 49.06% whereas non-beekeeping purposes had 50.94% in total. Non-beekeeping purposes had a slightly higher magnitude of destruction (28.45/53.17) compared to traditional beekeeping purposes (24.72/53.17) (Table 1). The field survey encountered a total of 390 bark hives and 7 log hives. Of all the hives encountered 40 were forsaken and left on the ground while 357 were hanged on trees. Harvesting practices imposed colonies absconding to 51% of all visited hives (Fig. 2).

Table 1. Observed signs of human disturbances in the Kululu Community Forest, and their contribution to forest degradation (based on weighted impact score). Impact scores indicate the extent of destructive effects caused by human activity on the forest ecosystem.

Human activities	Observed signs	Impact scores	*fo*.km	Severity	%Severity
Traditional beekeeping and honey hunting signs	Bee camps	3	0.07	0.33	0.62
	Connecting barks	2	0.05	0.11	0.20
	Debarked trees	2	7.95	15.89	29.89
	Hanging forks	2	0.08	0.16	0.30
	Log hives	1	0.08	0.08	0.15
	Ropes	2	0.82	1.63	3.07
	Honey hunting	2	3.26	6.53	12.27
Non- beekeeping signs	Cleared land	5	0.01	0.07	0.12
	Poles	2	0.20	0.39	0.74
	Firewoods	1	0.05	0.05	0.10
	Drying racks_fishing	3	0.07	0.20	0.37
	Fishing camps	3	0.04	0.12	0.22
	Cattle bomas	5	0.08	0.39	0.74
	Cattle herds	4	0.37	1.47	2.77
	Drying racks_ poaching	3	0.01	0.04	0.07
	Saw pits	4	0.88	3.53	6.63
	Sawyers	4	0.03	0.11	0.20
	Tree stamps	2	11.04	22.08	41.53
			25.08	53.17	100.00

Observed signs for traditional beekeeping and honey hunting purposes included trees cut for bark hives (31.69%), bee camps (0.26%), connecting barks (0.21%), hanging forks (0.31%), honey hunting (13.01%), ropes (3.25%), and log hives (0.31%). Non beekeeping purposes included agriculture (0.05%), poaching (0.05%), fishing (0.42%), livestock keeping (1.78%), timber (47.64%), fuel woods (0.21%), and pole (0.79%) (Appendix2).

This study investigated the destructive impact of traditional beekeeping on forest ecosystems and also compared those with non-beekeeping activities. We noted shreds of evidence on traditional beekeeping practices, honey hunting, selective logging, livestock keeping, crop farming, uncontrolled fishing, and illegal hunting in the Kululu CF. Traditional beekeeping activities involved selective utilization of locally available woody plants for traditional beehives (bark and log hives) construction. Honey hunting targeted mostly intruded tree trunks with stingless bees. Overgrazing seemed to seldom affect mature plants (except for cattle 'bomas' that fueled the cutting of trees) but could interfere with plant regeneration impacting the succession of various plant communities. Selective logging mainly observed in Miombo woodlands and wooded grasslands resulted in the massive killing of mature wood plants, particularly *P. angolensis* and *P. tinctorius* species which might have affected adversely the tree abundance of the selected plant species (Brown and Gurevitch 2004). The observed cleared land for agriculture in shrubland would transform the shrubland into farmland thereby affecting the shrubby abundances and species diversity. Illegal off take of wild fauna might reduce species diversity hence degrading the forest ecosystem (Naeem et al. 1995).

Traditional beekeeping

Trees cut for traditional beekeeping purposes accounted for 49.06% of the total observed signs. Unlike log hive signs (0.31%), bark hives marked nearly one-third (31.69%) of all observed human disturbances (Appendix 2). Trees debarked for bark hive construction contributed 29.89% of the total magnitude of forest destruction whilst loghives had only 0.15% destructive effects (Table 1).

Study results supported the hypothesis that traditional beekeeping would contribute substantially to tree cuttings, thus affecting adversely the forest condition. The detected destructive impact of 34.23% contributed by traditional beekeeping targeted hive-bearing plants, also reported in other studies (Fischer 1993; Okoye 1999). The extensive use of locally available wood plants for hive construction, hive hanging forks (*Kontoro in Nyamwezi tribe*), hive connecting barks, and ropes escalates the rate at which trees are cut, and tree trunk parts chopped, thus causing the loss of melliferous plants (Okoye 1999). Tree debarked for bark hive construction had huge destructive impacts nearly 200 times higher compared to those used for log hive construction (Table 1). This result explains the need for the immediate arrest of bark hives as an important beekeeping tool in the area. However, log hives could still be used based on the fact that they are constructed from dead woods with less destructive magnitude to the forest ecosystem.

Nevertheless, tree cuttings for traditional beekeeping purposes are often species-specific mainly aiming at plants with interwoven fiber patterns such as *Brachystegia species* (Mickels-Kokwe, 2006). The species-specific and unplanned plant harvesting may lead to reduced plant species diversity and forest degradation (Naiman et al. 1993; Köster et al. 2013). The selective exploitation of *Brachystegia* species for beekeeping might consequently affect the forest species composition (Fuller et al. 1998). Even though beekeeping is considered subsistence economic and environmentally friendly activity, the use of wooded plant materials and low technological tools could merely overtone the realized benefits affecting the beekeeping industry in the long run.

Honey hunting

Trees cut by honey hunters for harvesting honey from stingless bees accounted for 13.01% of the total observed signs (Table 1) contributing up to 12.27% of the total destructive effect on the forest ecosystem (Table 1).

The search for bee honey marked the third most destructive activity in Kululu CF, causing the death of hollow trees or injuries which might impend tree growth rates making them susceptible to pests and diseases (Fischer 1993). Honey hunting is often considered separate from traditional beekeeping activities because hunters merely harvest honey without offering artificial habitations to bee colonies. During the process of honey hunting, most trees are completely cut down while others are not fallen but rather wounded as hunters try to hollow tree trunks for easy scooping of honeycombs (Okoye 1999). Honey hunting, therefore, reduces the abundance of most slow-growing wood plants rendering their possible local extinction.

Selective logging

Evidence for timber making accounted for 47.64% of the total observed human disturbances (Appendix 2). Logging included observed signs of tree stamps, sawpits, and sawyers which contributed 41.53%, 6.63%, and 0.20% of the total destructive impacts (Table 1).

Results indicated the highest destructive effect owing to the logging activities in the KCF. These results are in line with that of Hosonuma et al. (2012) where forest degradation was greatly derived from timber exploitation and logging in developing countries. The selective exploitation of *Pterocarpus* species for timber might consequently affect the forest species composition (Fuller et al. 1998). Disturbances caused by logging may create a conducive environment for the influx of invasive species rendering adversely the native community plant species diversity (Brown and Gurevitch 2004). Long-term changes in species composition combined with the colonization of invasive species in logged forests may humpers the re-establishment of native species (Brown and Gurevitch 2004). Further, logging in natural forests greatly affects rare species with few abundances resulting in decreased ecosystem values (Naeem et al. 1995).

Honeybee colony absconding

The absconding behaviour was slightly lower in bee colonies hanged near the river (46%) compared to those hanged far distant from the river (58%) Fig 2. All hives were encountered in open woodland vegetation.

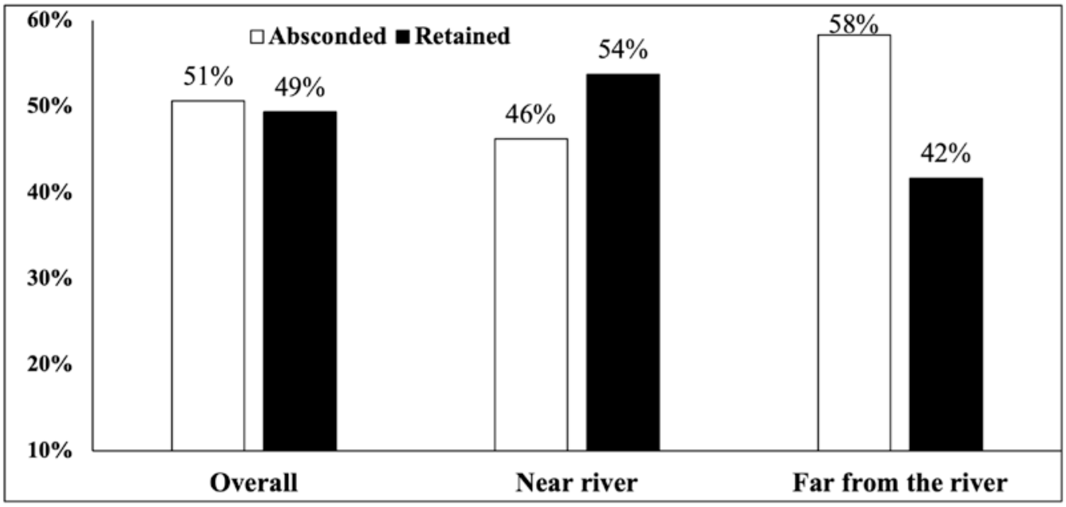

Fig.2: Comparison of bee colony absconding in hives hanged near the river versus those hanged far from the river in the Kululu Community Forest in 2022

Study results indicated that 51% of bee colonies abandoned their nests one week after honey harvesting justifying a strong connection between poor harvesting practices, and bee colony absconding as we predicted. These results are in line with a similar study in the region (Kuboja et al. 2020). Absconding behaviour was slightly lower in bee hives hanged near the river (46%) compared to those hanged atleast 10km far distant from the river (58%) Fig 2. The relatively lower absconding behaviour recorded in harvested hives close to the main river might be due to the fact that a moderate level of water and forage resources were still available during the harvesting period and thus bees might have absconded their hives merely due to inappropriate harvesting methods. However, forced absconding was not the only factor in areas far distant from the main river, rather, the scarcity of water coupled with the deterioration of melliferous plants in such a dearth period might have imposed resource-induced absconding, thus elevating the number of abandoned nests (Pradeepa and Bhat 2014; Winston et al. 1979). Traditional harvesting methods involved the removal of the entire set of honeycombs leaving bees with nothing to feed. In the process, some beehives were left on the ground making them susceptible to non-human predators and pests hence leaving bees with no options but abandoning their nests (Kuboja et al. 2020; Nurie 2020).

CONCLUSIONS

Study results indicate that nearly 35% of total destructive impacts on the forest ecosystem were due to traditional beekeeping practices hence surging for the immediate cessation of some practices such as the use of bark hives. Extensive beekeeping surveys in miombo woodlands are recommended to regularly examine and monitor the destructive impacts of traditional beekeeping in both community and government-managed forests. Inappropriate harvesting methods caused bee colonies to abscond in 51% of all visited hives. As such, beekeepers are advised to adopt improved hive technologies and beekeeping practices. Awareness campaigns on the impacts of traditional beekeeping and honey hunting should be integrated into extension services to raise community consciousness. Tree inventory surveys prior to harvesting, and forest management plans are extremely important in controlling logging in the area considering the high demand for timbers in the local and international markets. Extension services should aim at reducing the extensive use of bark hives and honey-hunting practices thereby offering training on the construction and adoption of intermediate, and modern beehives for both stinging and stingless bees. Moreover, government and non-government agencies should station beekeeping technical staff in villages as well as make sure that villagers have access to affordable beekeeping materials and extension services.

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APPENDICES

Appendix 1: Purposes of different human activities causing tree cuttings recorded based on observed signs in the Kululu Community Forest in 2022.

Purposes	Frequencies	Proportions	Percentages
Agriculture	1	0.0005	0.05
Bark hive	604	0.3169	31.69
Bee camp	5	0.0026	0.26
Connecting bark	4	0.0021	0.21
Firewood	4	0.0021	0.21
Fishing	8	0.0042	0.42
Hanging forks	6	0.0031	0.31
Livestock keeping	34	0.0178	1.78
Log hive	6	0.0031	0.31
Poaching	1	0.0005	0.05
Rope	62	0.0325	3.25
Pole	15	0.0079	0.79
Honey hunting	248	0.1301	13.01
Timber	908	0.4764	47.64
Grand total	**1906**	**1.0000**	**100.00**

Appendix 2: Percent of trees cut for different purposes recorded based on observed signs in the Kululu Community Forest in 2022*.*

RE-ASSESSING CHIMPANZEE POPULATIONS AND THREATS IN THE MASITO UGALLA ECOSYSTEM, TANZANIA.

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ABSTRACT

In 2022 we conducted a three-month follow-up chimpanzee survey in the Masito Ugalla Ecosystem to verify the estimation and assessment of populations and threats after conducting a similar survey in 2020. We used a similar methodology: Randomly generated 16 line transects with a length of 1 km on each site with a total of 28 survey sites. The sites were positioned based on chimpanzee habitat suitability models and previous surveys. We used Garmin 64s handheld GPS to navigate to the start and end points of transects and the ArcGIS Survey 123 App for data collection. We performed the data analysis using distance sampling software version 7.3. We used chimpanzee nest detections as a proxy for estimating the abundance and density of chimpanzees. The survey found that at least 657 chimpanzees live in this area (Min; 329 and Max; 1257, 95% CI). The average density of chimpanzees per sq. km was found to be 0.17 (Min; 0.09 and Max; 0.33, 95% CI). This number is low compared to that of a similar previous chimpanzee survey of 2020 which came up with a population size of 716 chimpanzees (Min; 413 and Max; 1301, 95% CI) and an average chimpanzee density per square km of 0.393159 (range: 0.210385 – 0.819905; 95% CI). While the decline was not significant, but still, a decrease of (59) 8% in this low population density is of major concern given the fact that chimpanzees grow slowly, reproduce late, and have longer interbirth intervals. Anthropogenic activities such as farming, settlements, cutting of trees, wildfire, and cattle herding continue to be major threats to the long-term survival of chimpanzees in the Masito Ugalla Ecosystem. These findings call for more deliberate actions to ensure the protection of these endangered chimpanzees, their habitats, and biodiversity in the Masito Ugalla Ecosystem.

Keywords*:* Chimpanzees, conservation, population, threats*.*

INTRODUCTION

Chimpanzees (*Pan Troglodytes*), our closest living relatives are facing great threats for their survival across a wide range of their habitats in Africa (Teleki 1989; Oates 2006; Plumptre *et al.* 2010; Hockings *et al.* 2015). At the beginning of 1900s, it was estimated that between 1 – 2 million chimpanzees were living in the wild across Africa (Walsh *et al.* 2003). However, this number has declined drastically and currently it is estimated that less than 300,000 chimpanzees have remained in the wild (Teleki 1989; Oates 2006; Kuhl *et al.* 2017). Because of this huge decline, chimpanzees are classified as endangered species on the IUCN Red List

(Oates 2006; Hockings *et al.* 2015). Many factors, especially those related to habitat destruction such as expansion of agriculture, human settlements, charcoal production, and logging have contributed largely to the decline of chimpanzee population size (Teleki 1989). Moreover, poaching for bush meats, as well as infectious diseases also have played a significant role in chimpanzees' population decline (Walsh *et al.* 2003; Kondgen *et al.* 2008; Pusey *et al*. 2008; Tweh *et al.* 2015). Given their life history traits, chimpanzees grow slowly and start to reproduce late which make them more vulnerable for their long-term survival when confronted with multiple anthropogenic threats.

In Tanzania, chimpanzees are naturally found in the three regions of Kigoma, Katavi and Rukwa (Kano 1972; Moyer *et al.* 2006; Ogawa 2006; Piel *et al.* 2015). Efforts to understand the population size and distribution of these chimpanzees started way back in the late 1950s by the expedition team of Japanese researchers (Kano 1972). In 1960, Dr Jane Goodall arrived in what was by then, Gombe Stream Game Reserves and initiated her long-term studies on the wild chimpanzees. Her groundbreaking studies increased our understanding of chimpanzee behavior and shed light on our closeness to chimpanzees (Goodall 1986). Her efforts eventually led to the establishment of the Gombe National Park in 1968. Similar efforts were also made by Nishida in Mahale and led to the gazettement of the Mahale Mountains National Park in 1985 (Nishida 2011). These two national parks provide a high status of protection to their chimpanzees. However, most of the Tanzania chimpanzees are found outside national park boundaries. They are in the districts and village forest reserves where protection for chimpanzees faces many challenges (Nishida 2011; Massawe 1992; Moyer *et al.* 2006; Piel *et al.* 2015; Chitayat *et al.* 2021).

For nearly 30 years, the Jane Goodall Institute (JGI) has been working with the villages, district governments, and other stakeholders on addressing threats that face these chimpanzees in the landscape of Western Tanzania, including periodic support of chimpanzee surveys. Because of limited resources and the expansive nature of the landscape, the chimpanzee survey has been restricted to a few sites therefore challenging availability of meaningful population size estimates to guide conservation and management decisions. In 2018, JGI was awarded a grant by the United States Agency for International Development (USAID) to address conservation challenges facing chimpanzees and their habitats in the landscape of western Tanzania. Following the grant, in 2020, JGI under the Gombe Stream Research Center (GSRC) led a three-month chimpanzee survey on the Masito Ugalla Ecosystem (MUE) within the Landscape Conservation in Western Tanzania (LCWT) project area. The survey findings showed that, at least 714 chimpanzees live in the MUE but under increasing anthropogenic threats. In 2022, again JGI though the USAID-LCWT Project conducted the second survey as a follow-up to estimate and assess how chimpanzees have performed in the subsequent years in the landscape.

MATERIAL AND METHODS

Survey Area:

The chimpanzee survey was conducted on the Masito Ugalla Ecosystem (Fig. 1). This region covers a total area of about 5,756 km^2 (Piel *et al.* 2015). On the east and north, the region is bordered by the Ugalla and Malagarasi Rivers, respectively. On the West and South, the area is bordered by a series of local villages. The region is found between an altitude of 900 and 1800 meters above sea level (Piel *et al*. 2017). On the eastern side the area is characterized by mountainous plateaus that are interspersed by emergent rocky outcrops in some areas while on the western side, the landscape is dominated by a series of rising and falling mountains with extensive plains in some parts of its ranges. Vegetation in the landscape is mainly characterized by the dominant miombo woodland of Brachystegia, Julbernadia, and Isoberlinia species, with galleries of riverine forest in some habitat's valleys (Moyer *et al*. 2006). The MUE receives annual rainfall of between 900mm and 1400mm, with November – April being the wet months, while the May – October season is considered dry months (Piel *et al*. 2017). Our survey was conducted during the dry season, from 10th August to 04th November 2022 to be able to compare the results with the 2020 similar survey which was also conducted in dry season.

Survey design

We adopted line transect locations and survey sites from the previous chimpanzee survey of 2020 (see Final Chimpanzee Survey Report July—October 2020). To improve our chimpanzee population size estimate, we increased three new survey sites based on the habitat suitability model (Jantz et al. 2016) and observations from survey of 2020 that made a total of 28 survey sites (25 existing, 3 new). See Fig. 1 below.

Fig. 1: Map of the Masito Ugalla Ecosystem showing Survey Sites and transects of the 2022 Chimpanzee Surey.

Survey team:

The survey team comprised a total of 24 individuals including personnel from JGI's Gombe Research Centre (GSRC), JGI-LCWT, Tanzania Wildlife Research Institute (TAWIRI), Tanzania National Parks Authority (TANAPA), Uvinza and Tanganyika District Councils, and the Village Forest Monitors (FMs). Most members of the survey team also participated in a similar 2020 chimpanzee survey conducted in the Masito Ugalla Ecosystem. The survey team was led by Dr. Deus Mjungu, the Director of GSRC, and coordinated by Paul Mjema, the GIS Manager of the LCWT project. To be able to cover all designated sites within the allocated time, the survey team was split into two sub-survey teams.

Refresher Training to the Survey Team

Before the start of the survey, the team leader in collaboration with the GIS Manager, conducted a refresher training for all the survey team members on data collection methods, how to use the GPS while navigating and how to capture field data using a customized questionnaire run by ArcGIS Survey123 mobile Application installed on smartphones. We also tested the inter-observer reliability and navigation skills of each observer before we started the survey. We used distance sampling survey methodology which is a widely used technique for estimating the size or density of biological populations (Thomas *et al*. 2010).

Data Collection:

We used customized questionnaire run by the ArcGIS Survey123 mobile data collection application installed on Android smartphones (Infinix Note 7) to collect chimpanzee survey data. On each transect, only one person was responsible for data recording. When chimpanzee nests were detected, observers recorded locations and associated data on ArcGIS Survey 123 data collection tool.

Photo 1: Fresh chimp nests from Sikonde 1 site

The perpendicular distances of nests to line transects were measured using a tape measure. Each nest was recorded and measured separately. Observers also noted the age of nests following Piel and others (2015) and rated their age on a 5-class scale. Number 1 indicated that the nests had fresh leaves *(example see Photo 1),* structure intact and sometimes with fresh feces underneath, 2: some leaves were brown, but the structure was still intact, 3: leaves decay and structure disintegrating, 4: only frame remained with less than 5% of the leaves and 5: no leaves and structure disintegrated. Observers also described vegetation characteristics and habitat types of the areas they passed during the survey.

In navigating to the transects, observers used handheld GPS (Garmin 64s) to locate start, direction, and end points of the transects.

Because vegetation cover in the survey area was dominated by the miombo woodland, we assumed that observers could detect observations of interest up to 50 meters on both sides of the line transect or recess. The area covered is shown in figure 2.

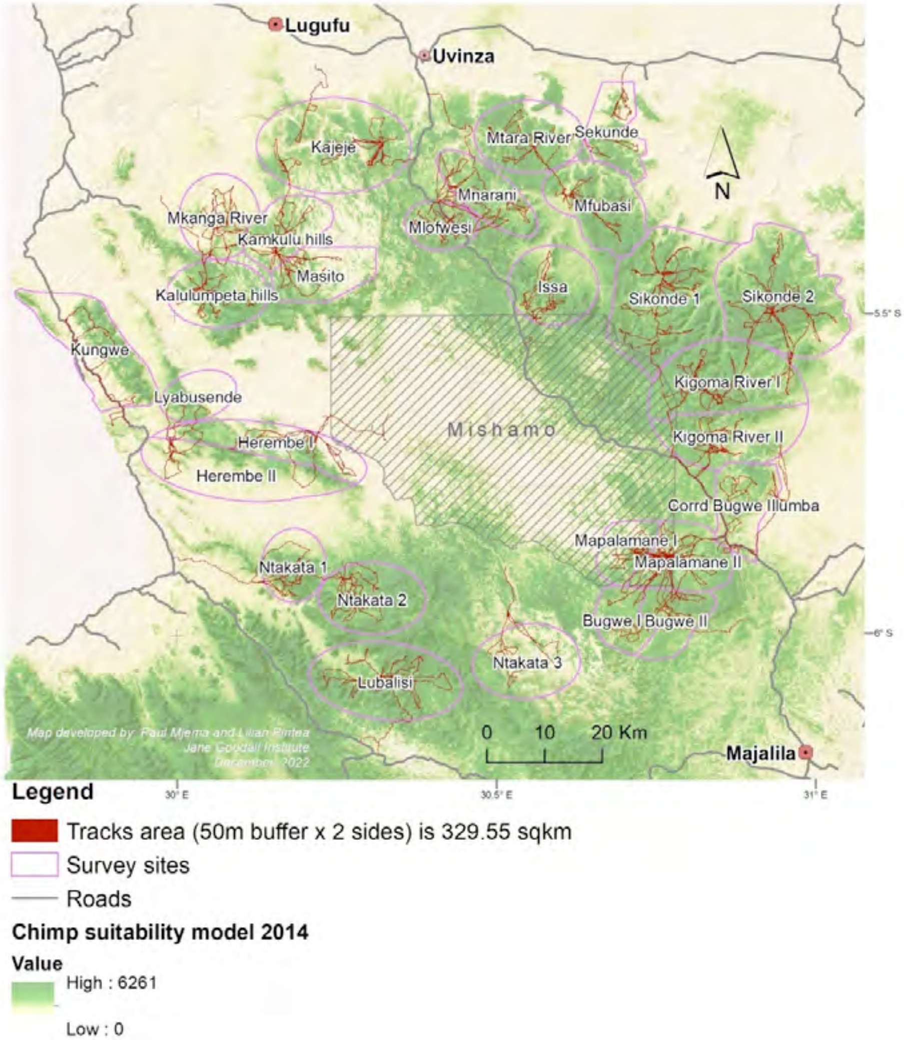

Fig. 2. Map of the survey area showing all efforts on line transects, and reconnaissance (recce).

We set camera traps in some strategic areas whenever possible to assist in getting images of elusive chimpanzees and other animals that were inhabiting the surveyed area. We leveraged reconnaissance (recces) walks to record chimpanzee nests and all observations of interest we encountered while traveling toward the transect lines, or after completing surveying a specific transect when moving to another transect, or when traveling back to camps.

Data Analysis:

Unhabituated chimpanzees are mostly elusive. Estimation of abundances and densities from chimpanzee nests detection has shown to be a good proxy for the estimation of population size (Marchesi *et al*. 1995; Plumptre and Reynolds, 1996; Kühl *et al.* 2008. Thus, we used chimpanzee nest detections to estimate the abundance and densities of chimpanzees in the Masito Ugalla Landscape. During the survey, we encountered a total of 1873 nests, with 1335 nests being detected while on the line transects.

In the analysis of the chimpanzee population, we used only nests that were detected while on the line transects. Data analysis was performed using DISTANCE sampling software version 7.3 (Thomas *et al*. 2010). To improve our estimates and decrease variation among sites we grouped the surveyed sites into six blocks *(see Fig. 3 below).*

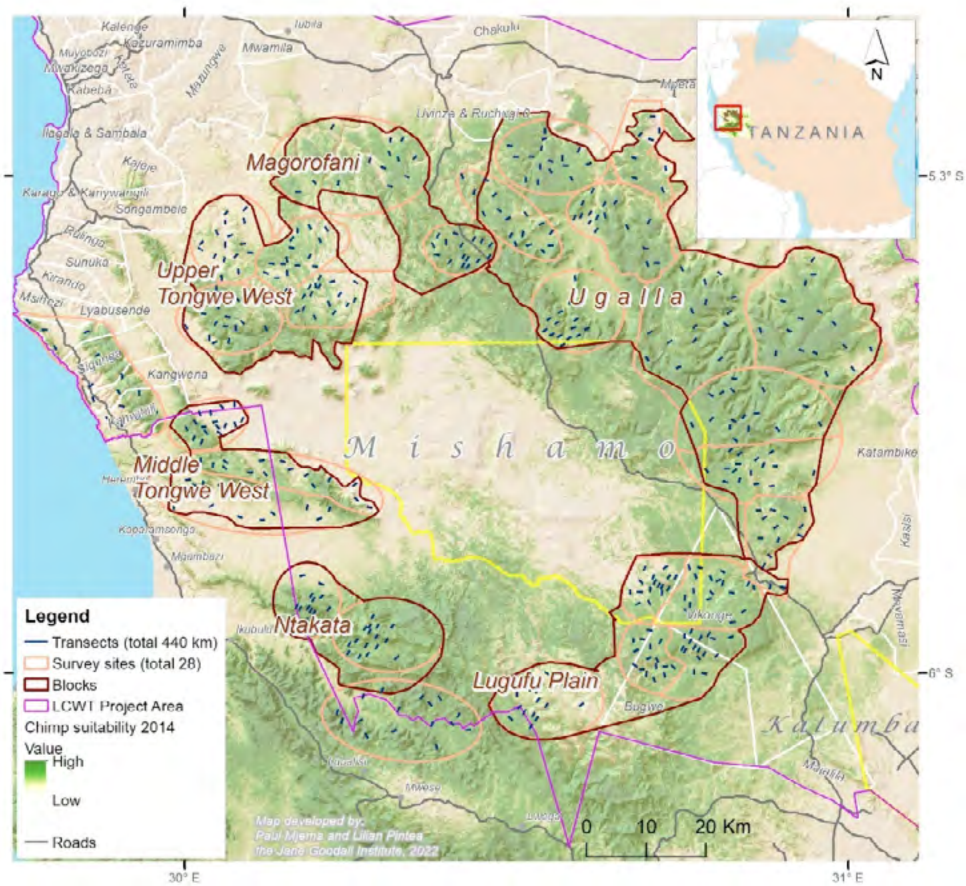

Fig. 3. Blocks used for population estimates of chimpanzees in MUE landscape.

The grouping assignment was guided by the contiguousness of the sites, the types of habitats, and the history of previous surveys in the area (Fig. 1). While grouping the sites, we ensured that our blocks adhered to the recommendation of at least 60 sightings when fitting the detection function in the distance sampling (Thomas et al., 2010). While creating population estimates for a specific block, we calculated a weighted average of the estimates for each site in each block, then we added the results to obtain the estimate for the entire area. We truncated all nests that were beyond 50m from a line transect during our analysis and restricted our analysis to nests that were under the age of four as per Piel and others (2015). The survey area for each site included all forest, woodland, and grassland within 50m on either side of the transects.

Table 1: Names of blocks used for estimating abundances and densities with their respective survey sites and areas.

Block Name	Grouped Sites	Area (sq Km)
Ugalla	Mtara River, Mfubasi, Issa, Kigoma River I&II, and Sikonde I&II	2282
Lugufu Plain	Mapalamane I&II, Bugwe I&II and Ntakata III	769
Ntakata	Ntakata I&II	376
Middle Tongwe West	Herembe I&II and Lybusende	413
Upper Tongwe West	Masito-Kalulumpeta-Kamkulu-Mkanga	659
Magorofani	Kajeje-Mlofwesi	475
TOTAL		**4974**

MODEL SELECTION AND CHIMPANZEE POPULATION ESTIMATES

On each block, we performed separate analyses by running seven models i.e., Uniform (with cosine adjustment), Half-normal (with cosine, simple polynomial, and Hermite polynomial adjustments), and Hazard rate (with cosine, simple polynomial, and Hermite polynomial adjustments). The models for abundance and density estimates were selected based on Akaike Information Criterion (AIC) (Boykin et al 2023). On each block, we used the nest decay rate of 139.2 days with the nest building rate of 1.1 (Piel *et al*. 2015.

RESULTS

Evidence of the presence of Chimpanzees

We saw chimpanzees directly on eight different occasions, group sizes ranged from one to 11 individuals. We heard chimpanzees' calls (pant-hoots) on 36 different encounters and collected a total of 65 fresh chimpanzee feces. Feces (fecal samples) are valuable resources, especially in the studies of gene flow, connectivity, and disease dynamics (Bonnin *et al*. 2022. The camera traps captured multiple images of chimpanzees from all six survey blocks *(see example in photo 2)*

Photo 2: Some of the chimpanzees as captured by one of the camera traps during our chimpanzee survey.

CHIMPANZEE POPULATION SIZE AND DENSITY

We estimated the abundances and densities of chimpanzees separately from each block (Table 2). We then summed all abundances and obtained a total population size of 657 chimpanzees (Min; 329 and Max; 1257, 95% CI). For the density, we found an average density of 0.17 (Min; 0.09 and Max; 0.33, 95% CI) chimpanzees per square kilometer.

Table 2: Estimation of chimpanzee population abundances and densities.

Block Name	Abundance			Density		
	Estimates	***Lowest CI***	***Highest CI***	***Estimates***	***Lowest CI***	***Highest CI***
Ugalla	297	170	518	0.22	0.13	0.39
Lugufu plain	20	7	57	0.03	0.00	0.07
Ntakata	188	106	335	0.53	0.33	0.86
Middle Tongwe West	56	26	121	0.14	0.06	0.29
Upper Tongwe West	52	8	164	0.08	0.01	0.25
Magorofani	44	12	60	0.04	0.02	0.09

In the comparison of chimpanzee abundances in 2020 and 2022 *(see figure 4 below),* we found that chimpanzee population has decreased by 8%. However, the decrease was not statistically significant (t-test: t = 0.14084, df = 9.8487, p-value = 0.8908). The increase of three new survey sites (Mnarani, Kungwe and Lubalisi) in our analysis of abundances of the 2022 dataset increased the population size to 670 (Min; 364 and Max; 1255, 95% CI).

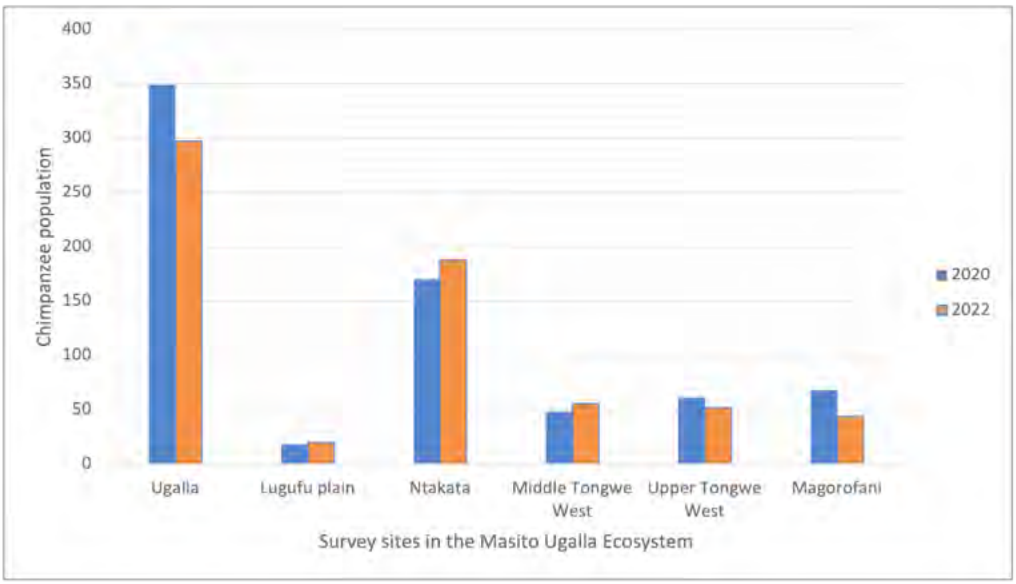

Fig. 4: Comparison of chimpanzee population estimates in six blocks of MUE in 2020 and 2022.

Other Biodiversity:

Apart from chimpanzees, we also encountered many other wild animals including lions, leopards, wild dogs, snakes, elephants and many different types of ungulates (see photo 3). The Ugalla block and Ntakata woodland forest continued to support substantial numbers of wildlife, respectively. Of course, we also saw animals on other sites.

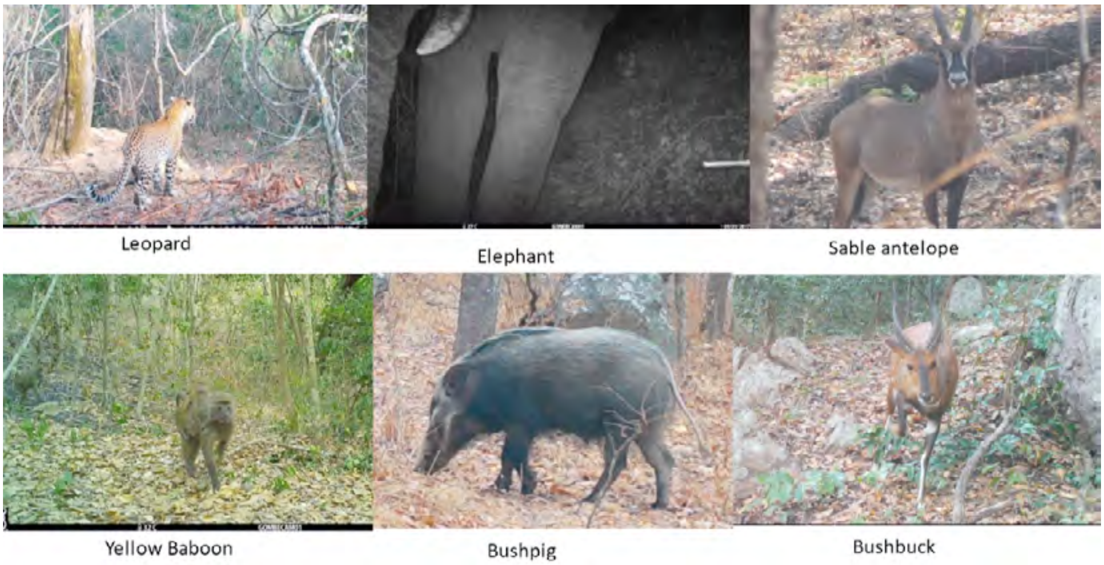

Photo 3. Other wild animals detected during chimpanzee survey

Anthropogenic Threats to chimpanzees and habitat:

Some of the anthropogenic threats we encountered during our survey included expansion of agriculture, scattered human settlements, tree cutting (Photo 2& Photo 5), logging, charcoal production, traditional destructive method of making beehives, uncontrolled bushfires, livestock grazing, and livestock enclosures.

Photo 4&5: Some trees cut and settlements we encountered during our survey.

Human threats on the landscape were not uniform. Some areas faced more threats than other areas. Tree cutting was more common in the Ugalla areas than in other areas, while settlements and farming appeared to be predominant in the Lugufu plain. Livestock grazing was widespread on the landscape.

DISCUSSION

Chimpanzees continue to persist in the Masito Ugalla Ecosystem (MUE) landscape. Our survey found that at least 657 chimpanzees still living in this area. However, this number is lower compared to that of the previous chimpanzees of survey of 2020. While the decline was not statistically significant, a decrease of 8% on this low population density species is of major concern given the fact that, chimpanzees grow slowly, reproduce late and have longer interbirth intervals. These life histories parameters make them more vulnerable to recover when the population size is decimated. For example, in the Gombe National Park, because of its small chimpanzee population size, females seem to have negative reproduction rate (Campos *et al*. 2022). This is not good for the Gombe chimpanzees as it suggests that a population is in an extinction vortex. In fact, chimpanzees have already been exterminated in some parts of their range in the western part of the country (Ogawa *et al.* 2006). Thus, there is an urgent need to find a solution to avert a trend of population decrease on MUE chimpanzees.

Anthropogenic threats seem to be on increase in some parts of MUE. Expansions of agriculture and human settlements were evident during our survey. Agriculture is mainly targeting the riverine areas. Unfortunately, riverine habitats although cover only a small part of the total area of the landscape (Piel *et al* 2015), they are important for chimpanzees' survival. Chimpanzees depend largely on riverine areas for their food and shelter. Chimpanzees' food which constituent largely of fruits are in good supply on riverine habitats. Thus, continuing farming in these areas leave chimpanzees with limited options for their diet particularly in dry months. The situation seems to be critical in some areas of the landscape. For example, in the Lugufu plain and some parts of Ugalla, farmlands are so extensive and have left chimpanzees in isolation on the mountain hills. At the Tongwe West, a potential corridor which is connecting chimpanzees and allowing them to access food resources towards the Lake side is continuing to be compromised by farming, leaving chimpanzees at the risk of being killed when venturing on those areas and denying them access to other part of their range. Similarly, a corridor between Ugalla and Lugufu plains is also facing similar challenges with hundreds of farms particularly paddy farms.

Photo 6: Some of the cattle observed during chimpanzee survey on the MUE landscape.

Unplanned human settlements are equally threatening the survival of chimpanzees. Normally a large patch of a forest is cleared to create a space for erecting houses and a buffer area from the wild dangerous animals. This practice causes an increase in forest fragmentation and leave chimpanzees with the option of living in forest pockets or force chimpanzees to vacate to other places which may not be easy to find.

Livestock encroachment to chimpanzee habitat continue to be a pertinent problem on chimpanzees' survival on the landscape (Photo 6). Indiscriminatory clearing of the forest by livestock keepers for making cattle enclosures (bomas) or burning areas to stimulate regrowth of fresh grasses, degrade quality of the chimpanzee habitat and contribute to forest fragmentation. In addition, the use of domestic dogs for scaring big cats like leopards or hyenas may equally scare chimpanzees and force them to vacate a nearby area. Although chimpanzees can adapt and live in disturbed areas, they flourish well in areas far from human disturbance. Furthermore, dogs can become a potent danger to chimpanzees, especially when accompanied by poachers. Diseases potentially transmitted to chimpanzees from livestock, dogs and people could be another important indirect threat from increasing livestock expansion. Studies from other sites show infectious disease to be the main cause of deaths to known chimpanzees (Pusey *et al*. 2008). Given the high interaction between people, livestock, and chimpanzees in the area, understanding the relationships between the health of chimpanzees, people, livestock and other domestic animals needs urgent focus and research using an integrated One Health approach.

CONCLUSION

The findings of the follow up survey shows that the number of chimpanzees found in 2022 is 657 which is low compared to the number found in a similar previous chimpanzee survey of 2020 that came up with a population size of 716 chimpanzees. While the decline was not statistically significant, but still, a decrease of (59) 8% in this low population density is of major concern given the fact that chimpanzees grow slowly, reproduce late, and have longer interbirth intervals. Anthropogenic activities such as farming, settlements, cutting of trees, wildfire, and cattle herding continue to be major threats to the long-term survival of chimpanzees in the Masito Ugalla Ecosystem. These findings call for more deliberate actions to ensure the protection of these endangered chimpanzees, their habitats, and biodiversity in the Masito Ugalla Ecosystem.

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Thanks also to the colleagues at the Jane Goodall Institute Tanzania and USA for championing extensive chimpanzee surveys in Tanzania and this is one of them. We enjoyed enormous support from the Institute which made the survey to be completed as planned.

Finally, we want to thank all the survey members, too numerous to mention each one here for their passion, commitment and hard working brought during the three months of the survey that enabled completion of the survey.

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TRAUMATIC VENTRICULITIS IN AN ADULT OSTRICH: A CASE REPORT FROM DODOMA, TANZANIA

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ABSTRACT

An adult male ostrich (Struthio camelus) was reported to be sick in one of the wildlife gardens in Dodoma. The sick ostrich was among the three transferred ostriches from another farm about five months ago. The bird clinically was observed to have loss of appetite, lethargy, weight loss, frequent sternal recumbences and vomitus-like fluid materials. Haematological, Coprological and bacteriological studies revealed the presence of lymphocytic leukocytosis, monocytic leukocytosis, gastrointestinal worms, and Escherichia coli. This ostrich died after five days while being treated, the necropsy was performed immediately and it was found that, all organs were normal except for the proventriculus, gizzard and peritoneum. The metal objects with different sizes ranging from 1.5 to 5.5cm intact puncturing all muscle layers of gizzard, ropes of about half a kilogram and pieces of clothes in the proventriculus, and a blackish/blueish discoloration in the peritoneum were found on necropsy. Pathologically, the gizzard was atrophic, necrotic, and traumatized with metals, oozing contents into the peritoneum, with peritoneal discoloration. This was confirmed to be a chronic traumatic ventriculitis, resulting in impaired gizzard activities, feeding, nutrient balance, peritonitis and hence death of the ostrich. Behavioural problems such as disorientation stress, desertion stress or frustration concerning finding food and keeping the ostriches in areas with multiple activities that include pieces of sticks/wood, rubber tubes, bolts, nuts and nails, predispose the ostriches to foreign bodies into proventriculus and ventriculus due to their feeding behaviour.

Keywords: *E. coli*, Hardware disease, *Hymenolepis nana*, Ostrich, Proventriculus

INTRODUCTION

Ostrich (*Struthio camelus*) is the world's largest, heaviest and featherless living bird, belongs to the genus *Struthio* under the family *Struthionidae* in the order Struthioniformes. This bird has a body size weighing over 200kg with up to 3 m height (Adam *et al*., 2022). Globally, the ostriches are found in both free range in the wild mainly in Africa and captivity. The commercialization of ostrich farming reported to be established for the first time in South Africa in 1865 and spread gradually and reached more than one million ostriches in all farms worldwide by 1913 (Shanawany, 1999). Ostrich farming is done for commercial production of feathers, skin, and meat.

Ostriches are known for their resilience and adaptability to diverse climates and weather conditions. However, when their care, management, living conditions, and feeding are disrupted significantly, ostriches become susceptible to epidemic diseases. The vulnerability is particularly pronounced among baby ostriches, who exhibit heightened sensitivity to various diseases within their initial three months of life.

Samson (1997) studied that, the ostriches can suffer from various diseases, including problems with the digestive tract, musculoskeletal system, upper and lower respiratory tract, skin diseases, liver diseases, Salmonellosis, non-specific septicaemia, Trichinellosis, and the nutritional diseases such as osteomalacia, fat necrosis, and gout. The most common ostrich diseases are hemorrhagic enteritis, avian pox, Newcastle disease, and gastrointestinal disorders. The gastrointestinal disorders which mostly occurred in ostriches are impaction, hardware disease, cloacal prolapse, and bacterial enteritis

Epidemiologically, the increased mortalities and economic losses in ostrich farming are caused by gastric diseases. The digestive processes are affected by the damage of the gastrointestinal tract, which is caused by both infectious and non-infectious pathogens (Mendonça *et al*., 2010). The infectious enteritis in ostriches are most frequently caused by bacterial pathogens including *Escherichia coli, Campylobacter jejuni, Pseudomonas aeruginosa, Salmonella sp., and Clostridium* sp. (Herráez *et al*., 2005).

In contrast with other birds, the digestive system of the ostrich lacks a crop, making the oesophagus enters directly into a stomach (proventriculus) which is large, dilated, and thin-walled structure in the thoracic cavity.

METHODOLOGY

Case history

In early of January 2023 an adult male ostrich was reported to be in poor body condition with reduced appetite in wildlife captive facility in Dodoma, Tanzania. Detailed clinical observation revealed the animal to have loss of appetite, lethargy, weight loss, frequent resting on sternal recumbency and vomiting gelatinous fluid materials. The animal was not socializing with other two ostrich, in several occasion the bird was chased by the dominant male.

The animal was physically restrained and maintained on sternal recumbency for close examination, sampling, and treatment.

Physical examination

The physiological body parameters were examined and found as follows: the respiration rate 15 breath (cycles)/min and body temperature 43°C. Loss of body condition and medial bending of the 4th digit on the left leg were significantly observed. Body weight was estimated at 100kg.

Sample collection

Blood samples were collected from right jugular vein in EDTA and plain vacutainer tubes. Cloacal and oral-tracheal swabs were collected in a transport media and RNAlater, while faecal sample (droppings) was collected in a screwed bottle. The collected samples were kept in cool box with ice packs and transported to Teaching Animal Hospital at

Sokoine University of Agriculture (SUA) in Morogoro for haematolocal and coprological examination.

Sample testing

Blood samples in EDTA anticoagulant was used make thin smear in glass slide for examination of blood parasites using light microscope and examine haematological analysis using a Hematology Analyzer Machine. Faecal sample in 10% buffered formalin was used to examine gastrointestinal helminths eggs through sedimentation techniques. The fresh faecal smear on glass slides was used to examine presence of protozoan. The cloacal and oral-tracheal swabs were used to grow bacterial in MacConkey agar and incubated at 37^0C to culture bacteria, the isolated colony were smeared on glass slide fixed and stained for identification under the light microscope. Additionally, another pair of swabs in RNAlater® were taken for molecular detection of Newcastle Disease Virus.

Supportive treatment

Following clinical examination and sample collection, the ostrich was given a supportive treatment while waiting laboratory results. The supportive treatment included oxytetracycline 20% (Alamycin® by Norbook, UK), multivitamin (VITAPOWER®, Eagle Vet. Tech. LTD, Korea) and Dexamethasone (Dexakel 0.2®, KELA, Belgium) based on manufacturers recommended doses.

LABORATORY ANALYSIS

The laboratory results indicated the presence of Hymenolepis spp and *Escherichia coli* in coprological and bacteriological tests respectively, while the haematological findings are shown in the **Table 1** below.

Table 1: Haematological indicators with the Laboratory findings and normal reference values

Haematological indicator	Unit	Laboratory findings	Normal range	References
White blood cells	(m/mm^3)	88.19	5.5-21	Levy *et al.,* 1989; Mushi *et al*., 1999; Campbell, 1988; Olowookorum *et al.,* 1998; Palomeque *et al.,* 1991
Lymphocytes	(%)	76.5	22.23-39.8	Levy *et al.,* 1989; Mushi *et al*., 1999; Campbell, 1988; Olowookorum *et al.,* 1998
Monocytes	(%)	5	1.0-3.0	Levy *et al.,* 1989; Mushi *et al*., 1999; Olowookorum *et al.,* 1998)
Heterophils	(%)	18.3	56.1-75.95	Levy *et al.,* 1989; Mushi *et al*., 1999; Campbell, 1988; Olowookorum *et al.,* 1998)
Eosinophils	(%)	0.2	0.8-1.2	Mushi *et al*., 1999
Red Blood Cells (RBC)	(m/mm^3)	0.13	1.5-2.42	Levy *et al.,* 1989; Mushi *et al*., 1999; Campbell, 1988; Olowookorum *et al.,* 1998; Palomeque *et al.,* 1991
Haemoglobin (Hb)	(g/dl)	18.6	8.9-16.68	Levy *et al.,* 1989; Mushi *et al*., 1999; Palomeque *et al.,* 1991; Olowookorum *et al.,* 1998)

Treatment post-laboratory results

The ostrich was treated with Ivermectin 1% (Aether Centre (Beijing) Biology Co., LTD) once as antihelminth, Gentamicin sulphate 100,000 I.U (KELA, Belgium) for five days, and multivitamin 5ml (VITAPOWER®, Eagle Vet. Tech. LTD, Korea). Two days after the end of this treatment, the animal died. Then, the necropsy was performed.

Necropsy

A systematic necropsy was conducted starting with skin examination for any lesion on it. Thereafter, the skin was removed to check for injury or wound underneath followed by carcass opening. The blackish/bluish discoloration of the peritoneum was observed on ventral portion running from the testis close to bladder. On opening the gastrointestinal tract, a piece of cloth and about a half kilogram of ropes were found in the proventriculus (**Figure 1**), and seven pieces of sharp metal ranging from 1.5-5.5 cm were found intact punctured the ventriculus (gizzard). The ventral one-third of the gizzard was necrotic with massive muscle loss resulted into an opening through which the gizzard contents were oozing out into abdominal cavity. Hence, hardware disease was the cause of the ostrich death.

RESULT AND DISCUSSION

The findings in this case revealed that the dead ostrich was succumbed with multiple health complications including worms, *E. coli* and hardware disease. The eggs of other cestodes and *Hymenolepis* spp., and *H. nana* worm found in ostrich droppings indicate that the sick ostrich was infested with worms. *Hymenolepis nana* also known as the **dwarf tapeworm** is a species of tapeworm that can infect humans and other animals (CDC, 2017). The adult worm is small, measuring less than 40 mm in length and 1 mm in width with the life cycle involving two hosts: humans or other animals serve as the definitive host, while insects such as beetles and fleas serve as intermediate hosts (Chelsea & William, 2022). Infection with *H. nana* can cause a condition called hymenolepiasis, which is characterized by symptoms such as abdominal pain, diarrhea, and weight loss and most common in children, in persons living in institutional settings, crowded environments and in people who live in areas where sanitation and personal hygiene is inadequate (CDC, 2017; Chelsea & William, 2022).

Tapeworms in ostriches has been observed and reported for more than a century (Gordo et al., 2002). The praziquatel as a drug of choice has been used to treat *H. nana* and other flatworms in human (CDC, 2017; Chelsea & William, 2022) and in ostriches (Gordo *et al*., 2002; Heneberg & Casero, 2022). In some cases, the ivermectin has been used in ostriches for gastrointestinal and external parasites, however its efficacy observed to be high in nematodes (de Souza *et al*., 2012). The prescription of this drug to the ostrich also aimed at controlling the fleas which are intermediate hosts for *H. nana.* However, the animal died before being treated with praziquatel.

E. coli is one of the normal intestinal microflorae found in ostriches and birds (Amani *et al*.,2020). However, some strains are pathogenic to ostrich and there are differences between commensal and pathogenic *E. coli* isolates of ostrich (Scerbova & Lauková, 2016; Amani *et al*.,2020). The hemolytic *E. coli* can cause a great threat to ostriches especially, to those with immunocompromised conditions and young ones when transferred from nests to farm area (Cooper, 2005; Scerbova & Lauková, 2016). The pathogenic strains of *E. coli* cause colibacillosis in poultry, a disease which characterized with high morbidity and mortality in poultry (Gross 1994, Cooper 2005; Scerbova & Lauková, 2016). Despite of some resistance of *E. coli* on antibiotics including Gentamicin and Oxytetracycline (Scerbova & Lauková, 2016; Amani *et al*.,2020), the gentamicin remains to be the drug of choice in poultry for colibacillosis treatment. However, the use of gentamicin in this case rely more on isolation of *E. coli* rather than confirmation of colibacillosis.

The hematological study was conducted due to its importance on understanding the hematological and immunological patterns of the ostrich. In avian species, the leukocytes are in five types: lymphocytes, heterophils, basophils, eosinophils and monocytes. The hematological values presented in Table 1 show that the sick ostrich had high levels of leukocytes, lymphocytes and monocytes, while the levels of heterophils and eosinophils were low when compared to the normal values established in studies conducted by Campbell (1988), Levy *et al.* (1989), Palomeque *et al.* (1991), Olowookorum *et al.* (1998), and Mushi *et al*. (1999). This physiological shifts of both relative proportion of heterophils and lymphocytes, as well as total concentrations of leukocytes has been explained also by Scanes (2015). The similar marked increase in leukocyte concentrations have been observed in chickens with the parasite *Plasmodium juxtanucleare* and in botulism infected black-faced spoonbills (*Platalea minor*; Chou *et al*., 2008). In this case, increased concentration of leukocytes in sick ostrich is associated with *E. coli* infection.

Heterophils are major phagocytic leukocytes in avian like neutrophils in mammals (Harmon, 1998; Scanes, 2015). They have great role in innate immune system, including mediating the acute inflammation response (Shivaprasad, 2002; Scanes, 2015) and capability of broad-spectrum antimicrobial activity (Harmon, 1998). As the first line defense, heterophils characterized by its peaks at 12 hours (Harmon, 1998) and attracts lymphocytes in bacterial infections such as *Mycoplasma gallisepticum* in chickens (Lam, 2002).

Avian lymphocytes play great role in both humoral and cell-mediated immunity (Scanes, 2015). Leukopenia with lymphopenia has been associated with early response to corticosteroids in some birds and some viral infections (Campbell, 1994). However, the conditions like avian chlamydiosis, mycotic and bacterial granulomas, and massive tissue necrosis produce chemotactic agents for monocytes (Hawkey *et al.,* 1983; Campbell, 1994). Furthermore, the *E coli* infection with transportation stress have reported to increase monocytes levels in turkeys (Huff *et al.,* 2010). Concomitantly, the monocytes have chemotaxic effects on lymphocytes and heterophils as observed in chickens (Lam, 2002). For that reason, the hematological values from the sick ostrich reflects the immune response towards *E. coli, H. nana* and the chronicity of the traumatic ventriculitis which has been succumbed before its death.

Due to effects of EDTA anticoagulant and time from blood collection to analysis on ostrich hematology may lead to hemolysis (Hawkey & Dennett, 1989; Clark *et al.,* 2009), the use of blood in EDTA anticoagulant and the delayed time for testing the samples, which was more than 24 hours may have influence on the obtained hematological values.

Furthermore, the lesions found during necropsy due to sharp-metallic objects in the ventriculus were impairing the normal functions on the organ. The impaired activities of this 'grinding machine' cause chronic loss of its tissues and emaciation. Concurrently, the spillage of gizzard contents to the peritoneum leads to constant irritation which results to blackish/bluish discoloration observed as the result of immune response, hence peritonitis. Peritonitis due to infections was the main cause of death to the ostrich. However, the swabs for bacterial isolation of discoloured area and the tissues for histopathology were not taken during necropsy.

Impaction and hardware diseases are common gastrointestinal disorders in ostriches that are mainly due to errors in the flock management, stressful (translocation, ambient temperature change), low fibre nutrition, and sudden changes in feeding regime, pica due to mineral deficiencies and behaviour of ostrich on visual appearing objects (Mendonça *et al*. 2010; Cooper *et al*., 2010; Adam *et al*., 2022). Due to lack of crop in Ostrich anatomy, the powerful gizzard muscles forces ingested sharp objects into muscular wall (Smith, 2020) that predisposes the ostriches to high risk of gastrointestinal impaction and gizzard trauma. Normally, ostriches consume stones in their diet, and they are renowned for their ability to swallow unusual objects example, Samson 1996 reported on the consumption of 2.5 m of barbed wire by an adult ostrich (Samson, 1996).

The study confirms that traumatic ventriculitis is the primary cause of death of the ostrich, it is therefore recommended that the ostrich grazing areas must be free from sharp metallic objects, by using magnetic finder to identify and remove all metal objects and farmer are advised to minimize stress to ostriches and consideration of male to female ratio must be adhered.

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ENVIRONMENTAL RESOURCES AND ECONOMIC GROWTH: ACCOUNTING FOR ENVIRONMENTAL RESOURCES IN TANZANIA: A THEORETICAL REVIEW

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ABSTRACT

This paper has shed light on how Tanzania accounts for environmental/natural resources destruction in the calculation of the national income with a view to avoiding an ecological/ biodiversity bankruptcy and in so doing attaining greener economic growth. As a matter of fact, Tanzania has not been taking into account environmental/natural resource destruction in the calculation of the national income. Economic growth that has been sustained by Tanzania has not been green growth, since it has been attained at the expense of environment/natural resources destruction, for which, no deductions of the cost to the environmental resources have not been made. Failure to account properly for the natural resource destruction that occurs in the process of national income generation makes the national income unrealistic. Omissions of environmental destruction in the calculation of the national income make the country an ecological bankrupt, even if its GNP or GDP may be rising.

Keywords: *Biodiversity bankrupt, Deforestation*, *Environmental resources, Green growth, Tanzania*

INTRODUCTION

Economic theory studies aspects of economic life that answer questions like, what to produce, how to produce, and for whom to produce, so that scarce resources may be efficiently allocated with a view to maximizing human happiness. So long as natural resources were available in unlimited quantities, natural resources and environmental issues could have been simple social issues. It is only with the transformation of natural resources and environmental goods into economic goods that economists started applying economic principles and theories to natural resources and environmental issues (Karpagam 2001, Kolstad 2000). The abuse of environmental resources has transformed environmental resources into economic goods, through a reversal in the supply-demand relationship of environmental quality, that is, the demand for environmental quality has registered a drastic increase while the supply of clean air, water, and other resources has declined (Bilame 2020). The increase in demand for environmental resources is attributed to the affluence that accompanies economic growth and development. At the verge of subsistence, people always worry about the quality of nature. To be more specific, for poor communities what matters is survival that is sustained at the expense of natural resources and environmental goods degradation.

Use is made of nature both directly and indirectly to transform raw materials into final goods. During this production process, nature is polluted by emissions and wastes. Hence the conflict arises as a result of the incompatibility of the basic ecological system and the economic principles of business profitability, economic growth, and expansion of world markets (Arrow *et al*. 1996). To restore harmony, to reconcile the interests of human beings and nature--an ecological reorientation of the economic policy is required. Unless we derive unifying principles from these disciplines--ecology and economics--unless we adopt an ecological outlook that views society as a great interacting network of co-existing populations, many of our social and economic policies are doomed to failure (Arrow *et al*. 1996, Ekins 2000).

To this end, a country's national income which is defined as the total monetary value of goods and services produced in a given period of time usually one year must take into account natural resources and environmental concerns. Generally, Gross National Product (GNP) is the basis upon which countries are ranked from rich to poor. It is regarded as an indicator of a healthy economy--a rising GNP indicates that the country's health economy is improving and a falling GNP indicates a deterioration in the country's health economy as long as the environmental side effects of production and consumption activities were negligible and insignificant (Harris and Goodwin 2003, Davidson, 2000). However, today's economic activities result in significant damage to the environment and natural resources, which impose considerable costs on existing as well as on future generations. The particular way we measure GNP or GDP fails to consider environmental and natural resources concerns. In fact, GNP per capita does not by itself constitute or measure welfare or success in development. It does not distinguish between the aims and ultimate uses of a given product nor does it say whether it merely offsets some natural or other obstacle or harms or contributes to welfare (Karpagam 2001, Harris and Goodwin, 2003).

To this end, the objective of this paper was to make an analysis of whether accounting for environmental resources in Tanzania takes care of the negative effects brought about by the exploitation of those resources. Specifically, the study sought to shed light on the extent to which unsustainable harvesting of environmental resources and depletion of natural resources due to unsustainable human activities are indeed taken care of when computing the economic growth (GDP) of the country.

METHODOLOGY

The methodology that was employed by this study involved reviewing various documents and publications covering the subject matter. A descriptive critical analysis of the information obtained from those documents and publications occupied a central place. It should at this juncture be noted that information/data from those publications were those that show the extent of the environmental degradation that Tanzania has and is experiencing and whether the extent of such degradation has been taken care of in the course of computing national income (GDP) growth.

A REVIEW ON ACCOUNTING FOR ENVIRONMENTAL RESOURCES

Accounting for Environmental Resources in Books of Accounts

A country's economic bookkeeping consists of income and capital accounts. While income accounts produce the Gross National Product (GNP) figure, capital accounts track changes in wealth. As timber factories, textile mills, office buildings, and other artifacts become old and fall into disrepair, subtraction is made from the capital accounts to reflect their depreciation in value (Ekins 2000). However, no similar subtraction is made for the deterioration of forests, soils, air quality, and other natural endowments (Grossman and Krueger, (1995). When trees are cut and sold as timbers, the revenue from such sales is counted as income and reflected in the GNP. Surprisingly, no deduction is made for the deterioration of the forest's destruction of a natural resource (asset). Not making a deduction of the costs imposed on the destruction of the natural resource (forest), inflates the national income and wealth. A country with such inflated levels of GNP will be considered better off than it really is and will automatically be ranked higher on the economic performance scale (Davidson, 2000, Karpagam, 2001). To this end, a failure to account properly for the natural resource destruction that occurs in the process of national income generation makes the GNP unrealistic. Under such a scenario where omissions of environmental destruction in the calculation of the national income make the country an ecological bankrupt, even if its GNP may be rising.

The deficiency in the ability of the national income accounting framework to account for the environment arises mainly because of the inconsistent treatment of natural and manmade capital. There are three specific shortcomings (Karpagam 2001). These are:

- ✓ First, the conventional national income accounts system measures a nation's wealth in terms of manmade capital only and ignores natural capital. Though natural capital (e.g. exploitable forests, fish stocks, minerals, and other assets such as fresh air, water, and the like) are valued highly by society, they are not included in balance sheets. Although national accounts, allow for the depletion of manmade capital in arriving at an estimate of Net National Product (NNP) or national income, they fail to record the depreciation (depletion) of natural capital.
- ✓ Secondly, the costs of environmental protection, that is, the expenditure incurred to restore environmental assets (such as pollution control equipment and medical expenditures on pollution-related diseases) are included in the national income and show up income-generating activities. No allowance is made for the corresponding environmental damages. Such expenditures referred to as 'defensive expenditures' are 'regrettable necessities'. Environmentalists feel that they should be regarded as the costs of consuming other goods and services rather than as benefits. Private firms deduct defensive expenditures from value added. In contrast, national income accounting considers such defensive expenditures as productive contributions to national output, if they are incurred by the public sector or households. It is held that such defensive expenditures should also be deducted from GNP in its current form.

- ✓ Thirdly, any residual damage to the environment that has not been covered by defensive expenditure should also be deducted from GNP. Failure to do so will give an exaggerated estimate of the GNP. To avoid this, any pollution that remains should also be assessed in terms of its damage and the assessed value should be deducted from the GNP.

The calculation of the GNP/GDP is thus distorted in two ways by overworking undesirable outputs (pollution) and by ignoring beneficial environmental-related output. Forests provide the best example of the distortion arising out of the failure of the national income accounting to account for the depletion of the natural resource base upon which the production of wealth depends. Commercial felling of trees at rates greater than their regeneration increases current income levels at the expense of a decline in capital assets. Developing economies dependent on primary resources such as timber, minerals, and agricultural crops will be affected most if national income accounting excludes environmental factors.

Similarly, a failure to deduct damages done to the environment (pollution) while compiling the national income, leads to unrealistic GNP or GDP figure. The omission of environmental degradation in the compilation does not reflect sustainable income. Sustainable income is the maximum that can be consumed in a given period without reducing the amount of consumption available in the future period. Failure to measure sustainable income will affect development and growth. Of all the different concepts related to GNP, NNP or national income is considered to be relatively more sustainable because it deducts capital depreciation from GNP (Karpagam 2001, Davidson, 2000). However, GDP and GNP are more widely used because of difficulties associated with the measurement of capital depreciation. In spite of the difficulties in the measurements of capital consumption, environmentalists hold that allowances for capital consumption or depletion should not be confined to manmade capital alone, but should also be applied to natural capital such as forests, fish stocks, etc. Only when such adjustments are made will accosting reflect sustainable income or true income.

True income, in other words, refers to the maximum amount a nation can consume without depleting the stock of assets available for future generations. This requires allowance for depreciation and hence constitutes the difference between GNP and national income. Based on the same principle, environmentalists argue that GNP should be adjusted for the depletion of natural capital also; otherwise, income will be overstated. Environmentalists argue for three kinds of adjustments to national income to reflect the impact of income-generation activities on the environment. These are, as noted already, adjustments for the depletion of natural capital, adjustments for environmental degradation, and adjustments for defensive expenditure.

Real Calculation for the Value of Natural Resources

Adjustment for the depletion of natural resources requires that the stock of natural resources such as oil and gas reserves, stock of fish, forests, etc. should be treated in the same the way as stock of manmade capital. Thus, a reduction should be made for the depletion of natural capital. Under the conventional system, NNP would be defined as:

$$NNP = GNP\text{-}D_M$$

.Where "D_M" is the depreciation of manmade capital. If accounting is attempted for the depletion of natural capital,

Where "D_N" is depletion of natural capital. There are two ways of calculating D_N:

- ✓ Depreciation method
- ✓ User cost method

In the depreciation method, depletion is valued as that part of receipts from the sales of resources that can be uniquely attributed to that resource. Assuming zero extraction costs, whole receipts R would be attributed to the depletion of the resource. Hence environmentally adjusted GNP, referred to as, ENP, would be:

$$ENP = GNP\text{-}D_M\text{-}R$$

With the positive cost of extraction, "R" will include a cost element (like wages, rent, etc.); depletion then will be less than "R". The depreciation method is criticized for not making allowances for the depletion of natural capital in the expression of *GNP* or *GDP*. On the other hand, the user cost method provides for deduction in GNP or GDP by redefining "R". The user cost method is based on the principle that "R" the receipts from sale of a natural resource comprise of two elements: capital consumption or user cost method "U" and income "M" The recognition that the ownership of a natural resource confers an income advantage to its owners, makes all the difference. The relative shares of two elements--"U" and "M" in R depend upon the level of reserves, current rate extraction, and choice of discount rate to apply to future flows of income from sales. In user cost method R is defined as net receipts from sales, i.e. gross revenue from sales of the resource less purchase of current goods and services required to extract the resource.

The depreciation method estimates of income are significantly greater than estimates arrived at using the user cost method. This is because in the depreciation method depletion is expressed as:

- ✓ $D = R$ - Cost of extraction, whereas, in the user cost method,
- ✓ $D = R - M$ - Cost of extraction.

There is an additional income element to be subtracted and hence the residual estimate of depletion is less. In the user cost method GNP or GDP would be redefined to exclude the user cost depletion estimates. Hence income estimates using this method will be less than that of using conventional measures.

Environment degradation occurs when the quality of natural environment declines, caused by pollution of air, water, etc. Such degradation should be accounted for in the same way as the depletion of mineral resources discussed earlier above. However, practical problems of valuing the effects of such degradation are more severe than in the case of mineral resources. Deviation from an accepted environmental standard defined by the environmental authority is usually considered for measuring degradation. The cost of restoring prescribed quality/standards will give an estimate of environmental degradation. The definition of 'environmental standards' however, poses problems.

While estimates of depletion of natural mineral resources may be obtained using the replacement cost method or restoration cost method or willingness to pay method, degradation of environmental quality may be estimated using a willingness to pay method. Environmentalists argue that in addition to the depreciation of manmade capital and depletion of natural resources, costs of environmental degradation should be deducted from GNP/GDP to arrive at a sustainable national product.

In the conventional standard approach to national income accounting, defensive expenditures are treated as any other form of consumption and show up as income-generating activities. They are directly or indirectly included in GDP. Environmentalists argue that such defensive expenditures should be excluded from or at least deducted from GDP so as that we come closer to sustainable income. In the absence of defensive expenditure, there is environmental degradation--depletion of natural capital--identification and measurement of such expenditures pose challenges.

The practical, conceptual and theoretical limitations of attempting to measure the depletion of natural capital and identification of defensive expenditures are indeed overwhelming. However, such an environmentally adjusted GNP and NNP will provide a more useful guide to economic performance and therefore to policy than the conventionally defined GNP and NNP.

The Current Status and Practice for Tanzania Accounting for Environmental Resources

Physical assets such as building equipment are valued monetarily as productive capital, but natural resources, in general, are not. In current accounting practices, the costs of depreciation of manufactured assets are usually subtracted from, or "written off against," the value of production as the assets depreciate with age. "This practice recognizes that a consumption level maintained by drawing down the stock of capital exceeds the sustainable level of income. Natural resource assets are not so valued. Their loss entails no debit charge against

Tanzania is endowed with valuable renewable natural resources such as forests, freshwater, fisheries, and coral reefs. The Northern Highlands of Kilimanjaro and Mt. Meru, and the Southern Highlands near Mbeya provide fertile soils for agriculture and species-rich forests. The Eastern Arc and Coastal Forests are globally recognized biodiversity hotspots that contain some of the highest densities of endemic plant and animal species in the world. Forests and woodlands cover over 50 percent of mainland Tanzania and provide vital habitat for biodiversity, protect watersheds and deliver ecosystem services (URT, 2017).

Competing demands for and open access to many of Tanzania's natural resources are causing the resources' degradation and are limiting their ability to continue to provide goods and services. Demand for water is increasing faster than available supply, with conflicts over water becoming increasingly common as a result. Tanzania's renewable per capita freshwater resources have declined from more than 3,000 m^3 in the nineties to around 1,600 m^3 in 2015, which is less than 1,700 m^3 per capita, the threshold below which a country is considered water-stressed by the United Nations (World Bank, 2017b).

Poor land use and watershed management practices have led to the degradation of forests and watercourses, threatening the very natural resource base upon which Tanzania's economy and the poor depend on. Deforestation rates are among the highest in the world (Tables 1 and 2), with an estimated annual net loss of 483,859 ha over the period 2002-13 (URT, 2017). The country's unique wildlife assets have experienced an unprecedented crisis due to poaching, overcrowding, and the associated degradation of biodiversity. Overfishing and uncontrolled small-scale fishing are threatening the sustainability of fisheries, the resource base that many poor fishing communities depend on for their livelihood.

Table 1: Annual Net Loss of Forest Area: East Africa

Forest Area (Thousand Ha)			Average Annual Change Rate (%)		
	1990	**2015**	**1990-2000**	**2000-2010**	**2010-2015**
Kenya	4,724	4,413	-2.8	1.7	0.9
Malawi	3,896	3,147	-0.9	-0.1	-0.6
Mozambique	43,378	3,7940	-0.6	-0.6	-0.5
Tanzania	**55,920**	**46,060**	**-0.7**	**-0.7**	**-0.8**
Uganda	4,751	2,077	-2.0	-3.3	-5.5

Source: World Bank 2019

Table 2: Annual Net Loss of Forest Area: Top Countries in the World

Annual Forest Area Net Loss (2010-2015)		
	Area (Thousand ha)	**Rate (%)**
Brazil	984	0.2
Indonesia	684	0.7
Myanmar	546	1.8
Nigeria	410	5.0
Tanzania	372	0.8
Paraguay	325	2.0
Zimbabwe	312	2.1

Source: World Bank 2019

The poor are most affected by the degradation of natural resources. Land degradation has been found to increase the likelihood of household poverty, as it reduces agricultural productivity. Deforestation—among others caused by smallholder farmers' shifting cultivation and tree cutting for fuel wood and charcoal production— reduces water availability, thereby worsening poverty levels. Degraded fisheries, due to open access and insufficient regulation, limit the availability of fish protein for the coastal and great lakes communities. Not only Lake Tanganyika is a prime example of an area marked by a significant decline in fish catches due to overexploitation but also Lake Victoria whose Nile perch fisheries declined significantly (Bilame 2012). Other forms in which the poor are disproportionately affected by natural resources degradation is through the increased burden of disease: contaminated water, attributable to the lack of proper sanitation facilities, causes cholera outbursts (Penrose et al., 2010) and increases the proliferation of disease vectors such as mosquitoes.

Population and economic growth are driving the depletion of natural resources, and the degradation of ecosystems and habitats. The ecosystem services these resources provide are vital for the country's population. Particularly rural communities will be negatively affected by their degradation and overexploitation, as natural resources are a primary source of food and energy for them. The opportunity Tanzania faces is to reconcile the use of natural resources to meet the demands of the population and economy with the need to maintain functioning ecosystems. Reaching this balance will catalyze sustained growth. However, the current trend in the use of natural resources is not sustainable, leading to persistent degradation and loss of ecosystems, which constitute the main cause of natural capital loss. The extent of deforestation differs from one ecosystem or forest type to another. For example, a loss reported for mangrove forests in Tanzania mainland in a period of 25 years from 1980 to 2005 was 18% (FAO 2007).

As a resource-based economy with a high urbanization rate, Tanzania's environmental degradation undermines economic growth and quality of life and disproportionately affects the poor. Rapid economic growth through the liquidation of natural capital provides a temporary boost to the economy but fails to create a base for sustained advances in wealth and human well-being. On the other hand, a development that focuses on the efficient and sustainable management of natural capital lays the foundation for long-term inclusive growth. Based on the above discussion and data provided in Tables, one may ask some questions that call for food for thought. Does Tanzania's economic growth reflect green growth? Does economic growth take care of the negative effects brought about by the exploitation of environmental resources? Does the rising GDP in Tanzania indicate the country's healthy economy with respect to the environmental side effects of production and consumption activities? If answers to these questions are no, what should be done for Tanzania to attain a win-win solution?

Attaining a win-win solution implies nothing more than attaining economic growth that is green. Green growth acknowledges the trade-offs between growth and green. Production growth that is environmentally and socially sustainable enhances welfare the most, as environmental degradation and increasing inequality reduce welfare (Economist 2014). 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 it has been noted, 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 reduces 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 (World Bank 2013).

As timber factories, textile mills, office buildings, and other artifacts become old and fall into disrepair, subtraction is made from the capital accounts to reflect their depreciation in value (Ekins 2000). However, no similar subtraction is made for the deterioration of forests, soils, air quality, and other natural endowments (Grossman and Krueger, (1995). When trees are cut and sold as timbers, the revenue from such sales is counted as income and reflected in the GNP. Surprisingly, no deduction is made for the deterioration of the forest's destruction of a natural resource (asset). Not making a deduction of the costs imposed on the destruction of the natural resource (forest), inflates the national income and wealth. A country with such inflated levels of GNP will be considered better off than it really is and will automatically be ranked higher on the economic performance scale (Davidson, 2000, Karpagam, 2001).

Failure to account properly for the natural resource destruction that occurs in the process of national income generation makes the GNP unrealistic. Under such a scenario where omissions of environmental destruction in the calculation of the national income make the country an ecological bankrupt, even if its GNP may be rising and it is unrealistic. The rising GNP of a country that is associated with environmental destruction neither can be termed *green growth* nor *inclusive growth*

From a welfare-economics perspective, 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, Bilame 2020). To that effect, the core meaning of the concept of 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 proportion of the active working population (Jetske and Ezra 2015).

To this end, green economic growth takes into account environmental/natural resources destruction in the calculation of the national income with a view to avoiding ecological/biodiversity bankruptcy. An economic growth that is not green is likely to be attained at the expense of environment/natural resources destruction for which no deduction of the cost to the environment is made. If the deduction of the cost imposed on the environment is not made, the kind of economic growth (DGP) so far attained might not be realistic.

Conclusion and Recommendations

This paper has shed light on how Tanzania accounts for environmental/natural resources destruction in the calculation of the national income or GDP with a view to avoiding an ecological/biodiversity bankruptcy and in so doing attaining greener economic growth. As noted earlier on, 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 of growth and its distributional implications in both the short and the long run.

It is obvious from the reviewed literature that Tanzania has not been taking into account environmental/natural resources destruction in the calculation of the national income with a view to avoiding ecological/biodiversity bankruptcy. To this end, the economic growth that has been sustained by Tanzania has not been green growth since it has been attained at the expense of environmental/natural resources destruction for which no deduction of the cost imposed on the environmental resources is made.

Since subtraction is made from the capital accounts, say for factories and office buildings as they become older, similar subtraction should be made for the deterioration of forests, soils, air quality, and other natural endowments from the national income or GDP. When trees are cut and sold as timbers, the revenue from such sales is counted as income and reflected in the GDP. Surprisingly, no deduction is made for the deterioration of the forest's destruction of a natural resource (asset). Not making a deduction of the costs imposed on the destruction of the natural resources, inflates the national income and wealth. A country with such inflated levels of GDP will be considered better off than it really is and will automatically be ranked higher on the economic performance scale.

Failure to account properly for the natural resource destruction that occurs in the process of national income generation makes the GNP unrealistic. Under such a scenario where omissions of environmental destruction in the calculation of the national income make the country an ecological bankrupt, even if its GDP may be rising is unrealistic. The rising GNP of a country that is associated with environmental destruction neither can be termed *green growth* nor *inclusive growth*. This study recommends that Tanzania should strive to account properly for the natural resource destruction that occurs in the process of national income generation with a view to making GDP growth a reality.

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CULTURAL DIMENSIONS FOR THE CONSERVATION OF *BUCORVUS LEADBEATRI* AT MSWAKINI CHINI

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ABSTRACT

Birds, especially hornbills, have held symbolic and supernatural significance in cultures worldwide. The Southern ground hornbill, in particular, has played various roles in cultural practices within the Asian and African continents due to its distinct features. However, the species faces a decline in population, primarily attributed to habitat destruction, the live specimen trade, and its use in traditional medicine and beliefs. This research sought to identify cultural beliefs and practices associated with the Southern ground hornbill and assess their influence on the bird's conservation. Data was collected from 83 households through questionnaires in Mswakini chini, with the Maasai ethnic group being dominant among respondents. Interestingly, by majority (79.5%) had no cultural beliefs and also revealed that absence of cultural beliefs to be of death, seemed to negatively impact conservation efforts, as they induced fear and potentially harmed the bird. On the other hand, beliefs portraying the hornbill as a signifier of seasonal change, an eater of destructive insects, or a bird of God, were associated with conservation efforts, encouraging locals to protect the species to manifest their beliefs. The study successfully identified cultural beliefs linked to the Southern ground hornbill and shed light on the influence of specific beliefs on conservation efforts. This newfound knowledge could be instrumental in designing effective conservation initiatives. By promoting beliefs that positively influence species conservation and discouraging those that do not, efforts to conserve the Southern ground hornbill can be better directed and strengthened.of significance to the Southern ground hornbill ($p < 0.05$). Only 20.5% of respondents held beliefs related to the bird, and Bucorvus leadbeatri (the scientific name for the Southern ground hornbill) was not used in any cultural practices by 98.2% of participants. Certain beliefs, such as the hornbill being a signifier

Keywords: Birds, Conservation, Cultural beliefs, Southern ground hornbill, Traditional practices

INTRODUCTION

Background information

Birds play a significant role in the lives of people across virtually all cultures of humankind (Tidemann & Gosler, 2012). Historically, birds have been symbols in art, literature, and sculpture, they have been accredited with supernatural powers hence providing moral guidance to a particular community (Tidemann & Gosler, 2012). Since the culture of a community has either a negative or positive impact on involved species, it makes them relevant (Tidemann & Gosler, 2012).

Thus, traditional African cultural practices are generally built into ways of conserving and protecting natural resources against overexploitation through the use of taboos and totemic affiliation with localities and wild flora and fauna species (Kideghesho, 2009).

The hornbills are among the most recognizable birds in the world, many species have large body sizes, outstanding enlarged casqued, striking black-and-white plumage, and loud, far-carrying calls (Trail, 2007). Their characters make them involved in cultural beliefs and practices across continents worldwide and several hornbill species are used in the cultural beliefs and practices in the Asian continent (Setha, 2004). In the African continent, hornbills have been signatures of cultures associated with use and having roles ranging from usage in food, traditional medicine, and taboos (Msimanga, 2000; Tidemann & Gosler, 2012; Alves & Rosa, 2013).

The *Bucorvus leadbeatri* in particular is a perfect example of a species that has had consistent contact with various cultures for a long period and has the characteristics that could result in the development of many cultural beliefs and practices (Coetzee et al, 2014). These cultural beliefs and practices emerge from traits such as deep four notes booming all and denoting coloration (black, white and red) on their plumage (Coetzee et al, 2014).

Southern ground hornbill is also known for its large size about 90cm in height and weighing between (4–6kg), longevity (50-60years), slower production rate, long age to sexual maturity (4-6 years), and first breeding beginning above 10 years (Coetzee et al, 2014).

The species breed in pairs of cooperatively breeding groups having about 2-11 individuals also occupying large territories having densities of 1 group per 100km^2 and being entirely carnivorous birds foraging mainly on reptiles, amphibians, insects and animals up the size of hares (Kemp & Kemp, 1980).

The Southern ground hornbill is historically found in Southern Kenya, Rwanda, Burundi, south-eastern Democratic Republic of Congo, Tanzania, Zambia, Mozambique, Zimbabwe, south- west to Angola, northern Namibia, and South through Botswana and East South Africa, including Swaziland and Lesotho (IUCN, 2016).

The species is observed to be declining although the accurate records are unknown and the data quality is poor providing insufficient and unreliable information (Birdlife Zimbabwe, 2020). The conservation status of the Southern ground hornbill is declared Vulnerable (IUCN, 2016). Despite the international conservation status, the species is declared endangered in countries such as South Africa, Lesotho and Swaziland due to threats emanating from habitat degradation and loss (Taylor, 2015, pp. 191–121).

Unfortunately, the species conservation status is affected by human-induced factors such as trade in live specimens (Trail, 2007; Beastall et al, 2016), habitat destruction (Coetzee et al, 2014), indirect poisoning (Koeppel & Kemp, 2015) direct persecution (Theron, 2011), electrocution and use in traditional cultural practices and beliefs (Chiweshe, 1983). Their population is also influenced by biological factors such as slow reproduction rate, long age to sexual maturity (4- 6 years), longevity

(50-60 years), and first breeding beginning above 10 years and the fact is that the species is restricted to protected areas (Coetzee et al, 2014). This raises the need for research to ensure the maximization of protection of these species.

Bucorvus leadbeatri has been profoundly influenced cultural beliefs and practices, both positively and negatively. For instance, in Zimbabwe within the Ndebele culture, the bird is revered as a symbol of positive omens and is protected due to beliefs associating it with carrying the souls of the departed and bad luck (Msimanga, 2000). In contrast, beliefs that ascribe authority to leaders through rituals involving the beheading of these birds have detrimental effects, necessitating their capture and killing (Coetzee et al, 2014).

Despite the evident influence of cultural aspects on the conservation of Southern ground hornbills, this facet remains inadequately explored. Most existing knowledge on this subject is derived from the southern regions of the bird's African range, with limited insight into the cultural perspectives from the North, such as Kenya (Tidemann & Gosler, 2012) and Tanzania (Paul, 2007). Notably, the specific cultural dynamics in regions like the Maasai Steppe of Tanzania and the Tarangire-Manyara ecosystem have received minimal attention.

This research embarks on an intriguing journey into the realm of cultural dimensions associated with the Southern ground hornbill, with a particular focus on Mswakini Chini village. The aim is not only to document these beliefs and practices but also to uncover the intricate relationship between humans and this remarkable bird. This newfound knowledge is expected to play a pivotal role in catalyzing efforts and initiatives for the conservation of the Southern ground hornbill. This research also seeks to provide a pioneering model that can be extended to integrate cultural dimensions into Southern ground hornbill conservation across diverse ecosystems. This study aims to, identify cultural beliefs and practices associated with the Southern ground hornbill and assess the influence of cultural beliefs and practices in the conservation of Southern ground hornbill.

METHODOLOGY

Study Area

Mswakini is an administrative ward in the Monduli District in the Arusha Region of Tanzania. The ward covers an area of 319.3 km^2 and has an average elevation of 1,017 m. It neighbors the Tarangire National Park, Mswakini Juu, Naitolia and Lolkisale (figure 1). According to the 2012 census, the ward has a total population of 5,776 while that of Mswakini Chini village population size was 1,246 people with a total number of 570 households.

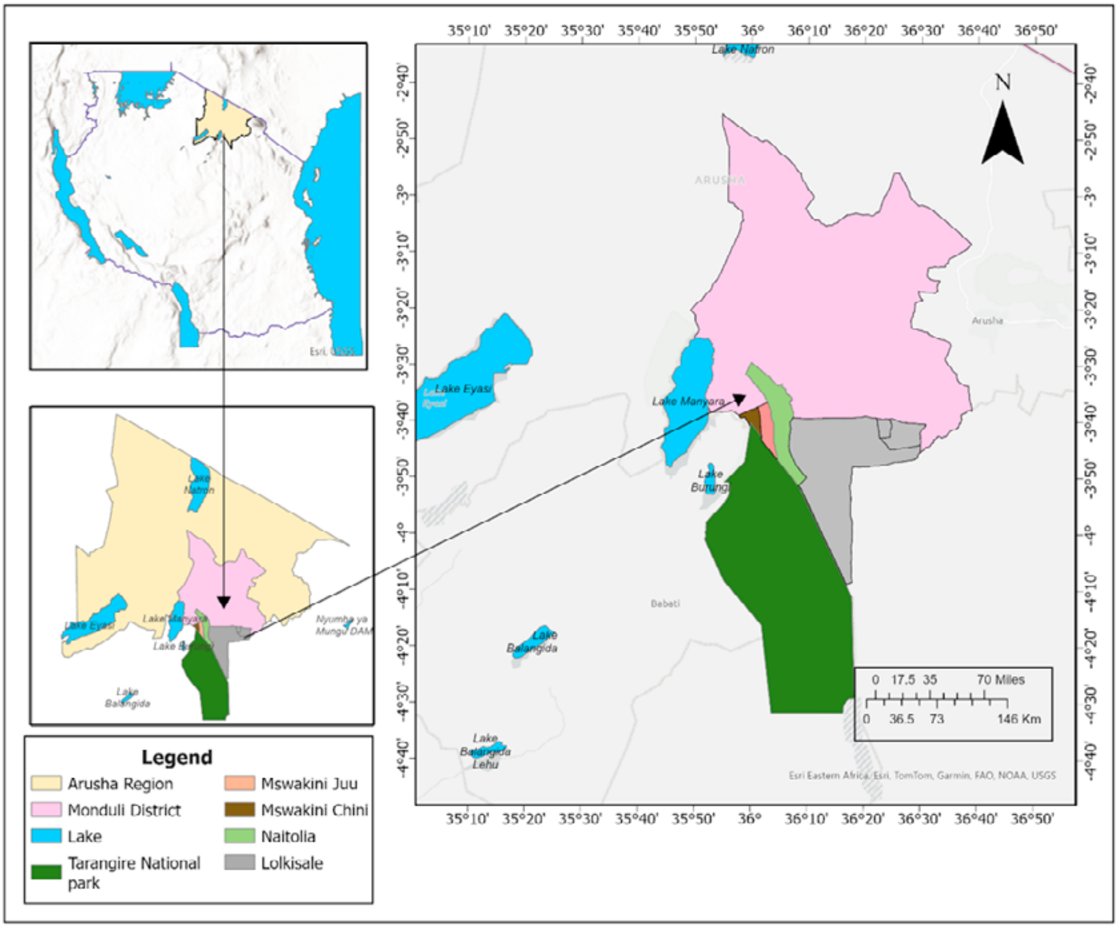

Figure 1. A map showing Mswakini Chini village

Mswakini Chini is located in the northeastern section of the country. Originating from the Monduli District located at latitudes 3°17’59” S and Longitude 36°27’00” E is characterized by plain land and open wooded grasslands. Mswakini chini has a semi-arid to humid dry winter climate, with altitude ranging from 560 to 2,123 meters above sea level, yearly temperature range of around 16^0C and 27^0C. It typically receives about 650 millimeters of rain annually (Mollel & Kaswamila, 2010, pp 184). Mswakini chini area has been occupied by people of different tribes such as Maasai and Waarusha.

The study applied a cross-sectional research design. The sample size was generated based on the sampling technique employed which was a simple random sampling technique (Kothari, 2004) and the data was collected using questionnaires and documentary review.

A total of 570 households was obtained from the village executive officer of Mswakini Chini Village. The sample size was generated using an online sample size calculator giving 83 households with a confidence interval of 95% and a margin of error of 10%. These were the sample size for the administered questionnaires.

RESULTS

Data from the questionnaire was analyzed using SPSS and a multinomial regression statistical test**.** The first objective was analyzed using the data from questions that looked into the identification of cultural beliefs and practices associated with *Bucorvus leadbeatri* whereby, descriptive statistics was performed in which the conclusion was made through graphs and tables to present findings. On the other hand, thematic content analysis was used to code, summarize, reconstruct, and categorize the responses related to the influence of cultural beliefs and practices from open-ended questions also the obtained themes were tabulated with their respective statements which aimed to analyze the second objective (Asefa, 2021a; Robinson, 2021).

The research findings in this part are divided into three sections demographic characteristics of the respondents, identification of cultural beliefs and practices associated with the Southern ground hornbill, and influence of cultural beliefs and practices in the conservation of the Southern ground hornbill.

The demographic characteristics collected for respondents in this study were gender, age, ethnicity, and occupation. From a sample of 83 households, the majority 67.5% were females and only 32.5%were males. This was because the study targeted the heads of households where most males leave early from their homes to perform other activities while women were left at home most of the time (Table 1). The age composition of respondents where, a large proportion of 38.6% of respondents were in the age group of 30-40, (24.1%) followed by the age group 19-20, (19.3%) age group 41-51, (9.6%), age group 52-62, (4.8%), age group 63-73 and lastly (3.6%), were the in-age group 74-84. No respondent was above 85 years (Figure 2)

As for ethnicity, respondents were dominated by Maasai (71.1%), followed by (20.5%) Waarusha, (4.8%) Iraqw, and lastly Kikuyu, Nyaturu and Pare each having (1.2%) of respondents (table 1). For the duration of stay by respondents in the village, a majority (37.3%) had lived for 21 years and above (Table1). The study also found that most of the respondents (48.2%), were performing both livestock keeping and crop farming activities, (28.9%) were only practicing crop farming, (12%), were business persons and (10.8%), were only practicing livestock keeping only. (Table 1)

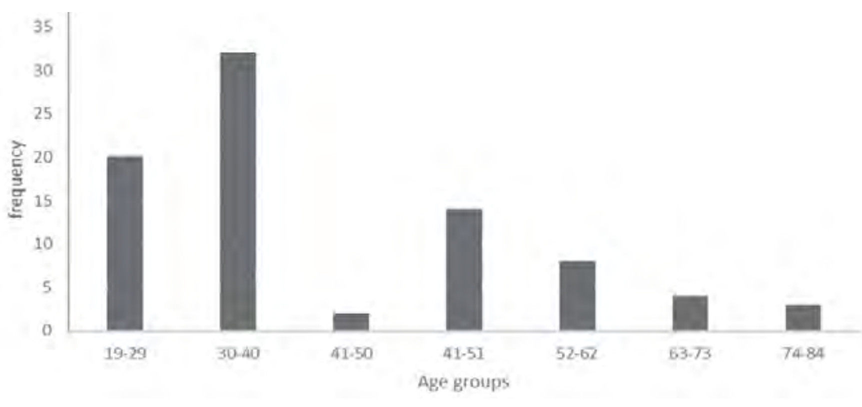

Figure 2. Age groups of respondents at Mswakini chini village

Table 1: Demographic characteristics of respondents at Mswakini Chini village

Gender	Female (%)	Male (%)	Total (%)
Duration (years)			
1-5years	9.7875	4.7125	**14.5**
6-10years	12.96	6.24	**19.2**
11-15years	9.7875	4.7125	**14.5**
16-20years	9.7875	4.7125	**14.5**
21 years and above	25.1775	12.1225	**37.3**
Total (%)	**67.5**	**32.5**	**100**
Occupation of respondents			
Livestock keeping	7.29	3.51	**10.8**
Crop farming	19.51	9.43	**28.9**
Both livestock keeping and crop farming	32.5	15.66	**48.2**
Business	8.2	3.9	**12**
Total (%)	**67.5**	**32.5**	**100**
Ethnic groups			
Maasai	47.99	23.11	**71.1**
Waarusha	13.84	6.66	**20.5**
Iraqw	3.24	1.56	**4.8**
Kikuyu	0.81	0.39	**1.2**
Pare	0.81	0.39	**1.2**
Nyaturu	0.81	0.39	**1.2**
Total (%)	**67.5**	**32.5**	**100**

The majority of the respondents (68.7%) in Mswakini Chini village could properly identify the Southern ground hornbill with only (31.3%) who could not identify the bird species (Table2). Furthermore, (43.4%) of the respondents were not aware of native name of the bird species, (31.3%) of the respondents stated none that there is no native name, (12%) named the bird nativelyas Ormotonyi, (4.8%) named it as Kukukeli, (2.4%) named it Orkurk, whereas names as Otai, Ormukuku, Orgorgor and Makuran'gai each having (1.2%) and lastly (1.2%) failed to rememberthe native name of the bird species.

Table 2. Identification of the Southern ground hornbill by respondent at Mswakini chini village

Responses	Percentage (%)
No	31.3
Yes	68.7
Total	100

The respondents were asked about cultural beliefs and practices associated with the Southern ground hornbill. As for beliefs, a majority (79.5%) had no beliefs and only (20.5%) had beliefs associated with the

Southern ground hornbill (see Figure 3). Where (12%) of the respondents believed it to be a signifier of change in seasons, (6%) of the respondents had other beliefs such as (2.4%) being an eater of destructive insects, whereas the presence of a good year, bird of God, and eater of carcasses in the wild each having (1.2%) and lastly signifier of death having (2.4%) (Figure 2). Furthermore, the absence of cultural beliefs was significant to the Southern ground hornbill conservation (23.653, $p < 0.05$).

Similarly, on the practices associated with the Southern ground hornbill, it revealed that the species was not used in any cultural practices of the respondents by (98.8%) and only (1.2%) responded to having used the bird species in circumcision and part used being the feathers.

Table 3. Themes influencing the conservation of Southern ground hornbill

THEMES	QUOTES
1. Signifier of change in Seasons	"If we see this bird, it means that the rains would begin. So, we have to prepare the lands for planting"
2. Signifier of death	"When the bird species lands on the roof, it is stoned away as it would indicate the death of an individual in the house"
3. Eater of destructive insects	"The bird once seen in farm areas; it feeds on the insects that destroy our crops (armyworms). Therefore, protecting our crops"

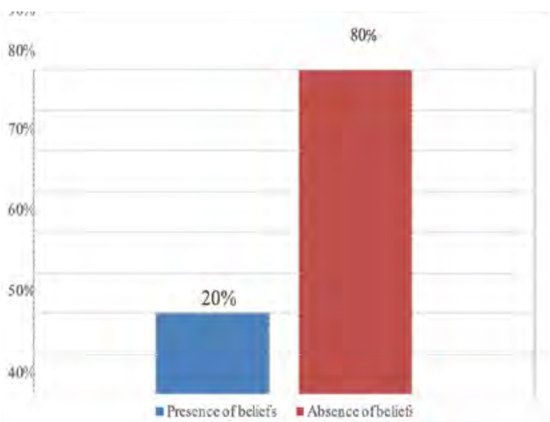

Figure 3. Distribution of beliefs among respondents in Mswakini chini village

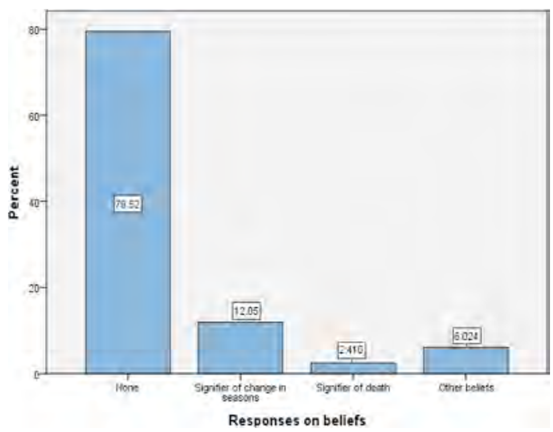

Figure 4. Beliefs associated with the Southern ground hornbill in Mswakini chini village.

DISCUSSION

In this study, more than 50% of the respondents demonstrated the ability to recognize the *Bucorvus leadbeatri* from a mere image. This compelling observation implies that the species frequently coexists with the local community, given its habitat's proximity to the village, particularly within open wooded grassland habitats. This mutual presence underscores the species' distinctiveness and highlights its visibility within the community's surroundings.

Demographically, the majority of villagers fell within the age group of 30 to 40 years and had resided in the village for 21 years or more. These long-standing community members engaged in a dual livelihood, encompassing both livestock keeping and crop farming, and were predominantly represented by the Maasai ethnic group, with a notable prevalence of females.

While these insights are valuable, the absence of prevalent cultural beliefs and practices associated with the bird species among the majority of the respondents was revealed. However, a few remarkable beliefs surfaced, such as viewing the bird as a signifier of seasonal change, an insect-eater, an indicator of prosperous years, a divine entity, and a scavenger of carcasses. This dearth of beliefs is attributed to the fact that the local residents in the study area do not engage in hunting activities as their primary occupation, unlike documented practices in semi-arid north-eastern Brazil, where beliefs are shared among friends during hunting activities or passed down by older generations (Monalisa et al, 2013).

Contrary to the findings of Coetzee et al. (2014), who reported diverse cultural beliefs associating the *Bucorvus leadbeatri* bird species with concepts of death, protection against evil spirits, timekeeping, and seasonal changes across the species' range in Africa, this study has unveiled the distinctive cultural milieu of Mswakini Chini village. The absence of these beliefs and practices in the local culture sets the village apart from regions inhabited by the bird species such as in Ndebele ethnic group from Zimbabwe, Mbuti, and Tongwe ethnic groups originating from Congo.

Furthermore, the research shed light on the absence of cultural practices linked to the use of the Southern ground hornbill, notably in the context of the Maasai community within the village. Instead, other bird species, such as ostrich, and plant materials play central roles in their rituals and cultural practices, as documented by Bussmann et al. (2006). In contrast, according to Alves & Rosa (2013) and Coetzee et al. (2014), the *Bucorvus leadbeatri* is used in various cultural practices, including traditional medicine and rituals, with different parts of the bird, such as the brain, feathers, intestines, bones, heart, and even the whole body, serving specific purposes. This difference is also echoed in Ichikawa's (1998) account of Mbuti hunters and gatherers stealing young birds from nests.

From a conservation perspective, the absence of cultural pressure on the *Bucorvus leadbeatri* species within Mswakini Chini village presents a favorable scenario. This absence of cultural practices that involve the species alleviates the threat of overexploitation for cultural purposes, thereby safeguarding the species from potential population decline.

However, the study revealed that some cultural beliefs and practices can still exert impacts on the bird species, despite the majority lacking such beliefs. Specifically, the act of hitting the bird species with stones, stemming from a belief that the bird signifies death, emerged as an impactful behavior. This behavior, rooted in fear and superstition, could potentially jeopardize the conservation of the *Bucorvus leadbeatri* species, in line with Asefa's (2021b) report of Oromo communities in Ethiopia killing large hornbills for examination.

Similarly, Coetzee et al. (2014) emphasized that cultural beliefs and practices can yield both destructive and non-destructive impacts on the bird species. The study findings call for interventions to mitigate the impact of beliefs that do not support conservation efforts, such as the harmful practice of hitting the bird with stones. Additionally, there is a need to emphasize and incorporate beliefs that positively influence the conservation of the species into formulated conservation strategies. This approach would not only make the local community feel actively engaged in the species' protection but also ensure that conservation strategies are culturally sensitive and efficient in implementation.

CONCLUSION AND RECOMMENDATION

The results obtained while assessing the cultural dimensions of Southern ground hornbill conservation in Mswakini Chini village have revealed an intriguing landscape. The absence of detrimental cultural practices offers a unique window of opportunity for the well-being of this species. Despite the absence of such practices, several enduring beliefs have emerged, emphasizing the bird's importance as a herald of changing seasons, a natural insect controller, a harbinger of prosperity and a vital component in the ecological cycle.

The knowledge acquired concerning these cultural beliefs and practices can be harnessed as a cornerstone for conservation efforts. To this end, a multifaceted approach is proposed to ensure the Southern ground hornbill's continued survival.

First, an extensive conservation education initiative directed towards the local community is recommended. This will illuminate the significance of the *Bucorvus leadbeatri* species and the various threats it faces. An understanding of the bird's biology and its ecological role will underscore the importance of its conservation. By fostering this awareness, we can collectively work toward safeguarding the species and preserving its essential place within the ecosystem.

Furthermore, it is essential to delve deeper into the role of the local community in the conservation of the Southern ground hornbill with respect to their beliefs. By understanding these roles, conservation efforts can be tailored to align with existing cultural dynamics and maximize their positive impact.

Additionally, there is a pressing need to broaden the scope of research to investigate other threats to the conservation status of the Southern ground hornbill, with particular attention to habitat destruction, especially within Mswakini Chini village. By examining this aspect, a more comprehensive view of the challenges facing this species can be gained and aid develop more effective strategies for its protection.

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EFFECT OF URBANISATION ON AVIAN COMMUNITY IN TANGA METROPOLITAN AREAS, TANZANIA

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ABSTRACT

Urbanisation has had profound impacts on wildlife including birds. Tanga, being the second largest city along the coast of Tanzania, is also subjected to high rate of urbanisation. We conducted a study to assess the impact of urbanisation on the avian communities in Tanga metropolitan areas. The study area was stratified into three zones with different levels of urbanisation; central business district (CBD), semi-urban (SU), and peri-urban (PU). Birds were sampled using point count method. The following environmental variables (urbanisation indices) were established at each census point: percentage cover of buildings, pavements, bare land, and vegetation, and number of parked vehicles and pedestrians. A total of 1358 individual birds from 28 families and 8 orders was recorded. Parked vehicles, buildings, pedestrians, pavements increased towards the CBD whereas bare land and vegetation cover increased towards the PU (χ^2 = 2313.808, df = 10, P<0.05). Avian species diversity decreased significantly (P<0.05) with the increase in urbanisation among zones: CBD versus SU, CBD versus PU, and SU versus PU. However, in the CBD there was a high abundance of the two alien bird species; the House Crow and House Sparrow. The first two axes of the canonical correspondence analysis scatter plot explained 62.72% and 37.28% of the variance in bird assemblages, whereby vegetation and bare land cover had significant influence in the distribution of birds than the rest of the environmental parameters. Because urban sprawl is increasingly affecting avian communities, it is worth considering some strategies to increase green spaces and managing urban gardens by planting native trees. Moreover, the dominance of alien bird species especially the House Crow in urban areas is not healthy for native avifauna; its population need to be controlled.

Key words: Alien bird species, Avian community, Urbanisation indices, Vegetation cover.

INTRODUCTION

Urbanisation is a process of population and housing concentration and is associated with transformation of land from natural habitats, agricultural areas to non-agricultural production, housing or trading. It is rapidly changing our world's face, reducing native habitats and affecting distribution, richness and composition of biological communities (Marzluff, 2001; McKinney, 2008). Most native species are pushed to remnant natural or semi-natural habitats (Haire et al., 2000), while few species become adapted to urbanisation depending on the urbanisation intensity. Avian is among the most cosmopolitan group, and has been used to study the effect of urbanisation in many parts of the world especially in developed countries (Marzluff, 2002). Urbanisation has increased tremendously in recent decades, and in 2009 more than half of the world's population lived in the cities. Much of the urbanisation takes place in low income developing countries, for example the urban population in sub-Saharan Africa increased from 11% in 1950 to over 35% now and is estimated to be more than 50% by 2040 (UN-DESA, 2012). Despite of recognition of the importance of urban and peri urban biodiversity, it has been claimed that peri urban areas, including reservoirs, green belts, and remaining natural habitats, support a substantial avian species assemblage. However, this diversity is negatively impacted by anthropogenic factors, including urbanisation and associated disturbances such as traffic, loss of green spaces, and physical presence of human and infrastructures. Urban areas are growing at fast rates and dramatically modifying preceding systems, and threatening biodiversity at different spectrum (Czech & Krausman, 1997). Cities can be recognised into intra-urban which refers to central business districts and peri urban areas. The Central business district (CBD) area represents the core of cities and are surrounded by peri-urban (PU) areas, where urban and non-urban elements integrate (MacGregor-Fors, 2010).

Although urban areas represent nearly 3% of terrestrial surface, their ecological impact goes beyond city limits generating environment changes at local and even global scale (Liu et al., 2014). As the consequences, several taxa are negatively affected by urbanisation (Chimaitelly et al., 2009). Given that cities are built to satisfy human requirements, they have a very similar structure around the world (McKinney, 2006), a few invasive species that are adapted to humans live in urban centres, whereas other widespread species adapt to residential and suburban areas (Blair 1996, McKinney, 2002). Generally, avian communities in urban areas are often characterised by generalist species and invasion (John & Kagembe, 2022). Bird species may respond differently to urban development and habitat fragmentation (Crooks et al., 2004). Earlier studies indicated that urbanisation results in increasing number of exotic species and decreasing of native species (Marzluff, 2001, Turner et al., 2004, John & Kagembe, 2022), this response patterns of total avifauna may be influenced by relative contribution of introduced and native species.

The whole of the coast environment not only in Tanzania but also throughout the world is under threat of habitat loss due to burgeoning urbanisation. Little is known on how wildlife particularly birds will respond to these changes, understanding responses is critical for designing management plans, and urban planning. Thus, this study aimed at assessing the impact of urbanisation levels on avian community in Tanga metropolitan areas.

METHODS

Study area

Tanga city is located in the northern east of Tanzania mainland along the Indian Ocean, lying between longitudes 38°53’ to 39°10’ east, and latitude 5°00’ to 5°16’ south. It serves as the administrative and commercial centre for Tanga region and has the second largest port in the country. It extends 20 km inland from the coast between 0-17 meters above the sea level. The landscape features rolling hills, valleys and streams. It occupies a land area of 600 km^2. The city boarders' Muheza district to west and south, Mkinga district in north and Indian Ocean to the east. Tanga city council is made up of four divisions Central, Ngamiani, Chumbageni and Mabawa, which are subdivided into 27 administrative wards, out of these 18 are urban and nine are peri-urban. According to the recent 2022 population and housing census, the total population of Tanga city council is 393,429 this marks an increase of 120,097 individuals compare to the 2012 census, which recorded a population of 273,332. This significant growth highlights a steady demographic increase over the decade. The data reflects the ongoing development and urbanisation within the region, contributing to the rising population number due to the presence of economic opportunities such as the recent improvements in Tanga port following the ongoing construction of the East African Crude Oil Pipe Line (EACOP) from Hoima (Uganda) to Tanga, which has attracted investors and human labour.

The study site was divided into three zones along an urbanisation gradient from CBD (Centre of the Tanga city), SU (suburban; urban centres/satellite towns) and PU (peri-urban; farmlands, scattered settlements, villages)

Data collection

Bird surveys were conducted using point count method (Biddy et al., 2000). Two roads, one running to the west towards Muheza and another on the south along Pangani road were selected as reference points and a total of 90 bird census points were established during data collection in all three zones (30 points in each zone). The systematic random sampling method was used to study birds on each zone and the distance from one point to another was at least 300 m (measured by using a hand-held GPS. Sampling at each point was done in an area with a radius of 50 m. Little attention was put on birds in the air. Bird survey was done twice a day from 07:00 to 11:00 and during the evening from 16:00 to 18:00. This is the time when most birds are active. A total of 20 minutes was used on each point to record birds and urbanisation indices. Bird identification was done with the aid of the of Birds of East Africa guidebook (Stevenson & Fanshawe, 2020).

The following urbanisation indices were estimated within 25 m radius at each bird census point: number of parked vehicles and pedestrians, percentage cover of pavements, buildings, bare land, and vegetation cover. The fieldwork was conducted in March 2023.

Data Analysis

The dataset was tested for normality by using Shapiro Wilk test before being subjected to statistical analysis to test for significance differences. Shannon Weiner diversity index was used to determine the diversity between three established zones (CBD and PU, CBD and SU, PU and SU), and species diversity test (Special t-test) was used to gauge the difference among the zones. Chi-square (χ^2) contingency table was used to determine association between environmental variables and the level of urbanisation among zones (CBD, PU and SU). Multivariate, Canonical Correspondence Analysis, was used to determine the relationship between bird's species abundance and environmental variables. All analyses were done using Paleontological Statistics (PAST) software.

RESULTS

Species composition

A total of 1358 individuals of 71 bird species were recorded belonging to 28 families within 3 different urbanisation zones belonging to 8 orders whereby the overall species richness of birds was highest in PU (49 species), followed by SU (45 species) and CBD recorded the lowest bird species (26 species). The dominant family in the study area was Nectariniidae and Emberizidae both constituting (17.85 %) of the total species, followed by Motacillidae (14.28 %), Meropidae and Ploceidae (10.71 %), Cuculidae (7.14 %) and Sturnidae (3.57 %). Passerines (order Passeriformes) had the highest numbers of all species observed i.e. about 80.55% of all individual observed.

A number of Palearctic migrants were also recorded during the survey such as Northern wheatear (*Oenanthe oenanthe)* and European Roller (*Coracias garrulus),* and some common Intra-African migrant species including the White-throated Bee-eater (*Merops albicollis)*.

At least three common non-native species were recorded during the survey. They include House Crow (*Curvus splendens)*, House Sparrow (*Passer domesticus)* and Feral Pigeon (*Columba livia)* (Table 1).

Table 1: Abundance of the introduced species in Tanga metropolitan area recorded this study in March 2023.

Species	Abundance	Percentage (%)
House Crow	335	24.67
House Sparrow	227	16.72
Feral Pigeon	23	1.3

Species diversity among urban zones

The Shannon-Wiener diversity indices decreased with urbanisation such that the CBD had the

lowest diversity, followed by SU and highest in PU and the difference between zones were significant (Table 2). Despite having the lowest species diversity CBD had highest species abundance. However, many of the bird's species that were found in this zone were concentrated in the green patches. The most abundant species with corresponding relative abundance were House Crow (24.7%), House Sparrow (16.7%), Common Bulbul (7.9%), Black-headed Weaver (5.7%), and Northern Carmine Bee-eater (5.2%). The least abundant species were Red-faced Crombec (0.15%), Purple-banded Sunbird (0.07%), Klaas's Cuckoo (0.07%), Trumpeter Hornbill (0.07%) and Grey-headed Bushshrike (0.07%) (Appendix 1).

Table 2: Bird species diversity between the urbanisation zones in Tanga metropolitan area.

S/N	Urbanisation zone	H' Value	P-Value
1	CBD and SU	1.983 and 3.056	$P < 0.05$
2	CBD and PU	1.983 and 3.328	$P < 0.05$
3	SU and PU	3.238 and 3.056	$P < 0.05$

Urbanisation indices

Characteristics of urbanisation in all three established zones didn't vary markedly. Built cover clearly differentiated CBD from SU and PU respectively. Similarly, vegetation cover, pavements, parked vehicles and human activity such as pedestrians separated CBD from SU and PU zones. Generally, the percentage of area covered by buildings, pavements and the number of parked vehicles decreased away from the CBD while that of vegetation and bare land increased from CBD to PU (Fig. 2). The data revealed a significant difference between the urbanisation levels from CBD, SU to PU (DF=10, α=18.31, χ^2 = 2313. 808, P<0.001).

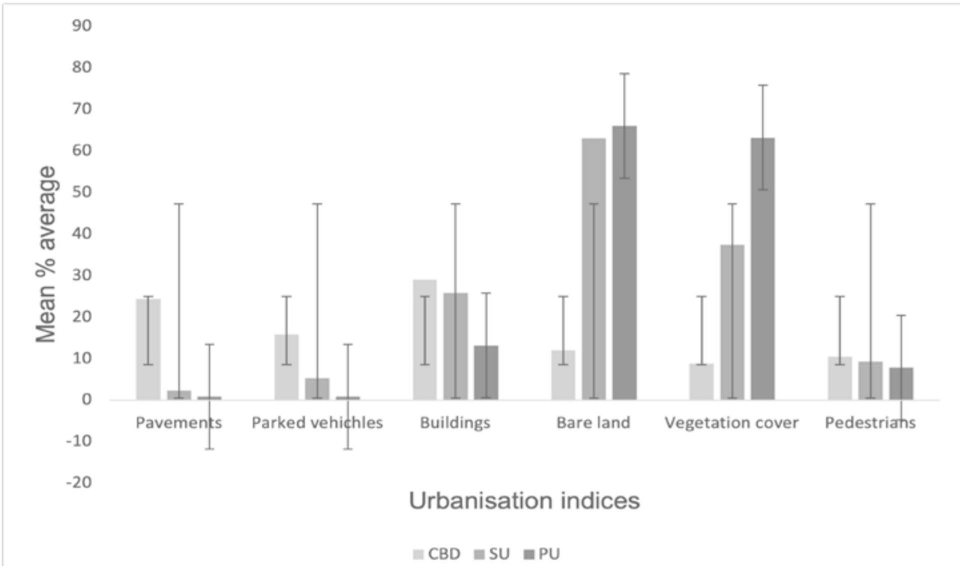

Figure 1: The variation in the urbanisation indices in different urban zones in Tanga metropolitan areas.

Relationship between avian assemblages and urbanisation indices

The first two ordination axes of the canonical correspondence analysis scatter plot explained 62.72% and 37.28% of the variance in the species data with canonical eigenvalues of 0.527 and 0.313 respectively. The permutation test results using 999 permutations showed that the overall analysis and the two axes were not significant (P=0.654). Axis 1, which accounted for 62.72% of the variance, successfully showed the relationship between habitat variables and abundance of bird species (Figure 2). Bird species with strongest positive association with axis 1 (see Appendix 1 for species names) were African Pied Wagtail, Brown-breasted Barbet, Common Bulbul, Scarlet-chested Sunbird, Speckled Mousebird, Striped Kingfisher, Little Bee-eater, Grassland Pipit, Village Indigobird, Northern Carmine Bee-eater, Red-cheeked Cordon-bleu, Red-fronted Tinkerbird, Cattle Egret, Yellow-rumped Seed-eater, Yellow-throated Longclaw, Zanzibar Red Bishop, White-browed Coucal, Tawny-flanked Prinia, Zanzibar Sombre Greenbul, Vitelline Weaver and Pied Crow.

The variables that were positively associated with axis 1 were vegetation cover and bare land. Contrary to that, on the decreasing strength of association bird species such as House Crow, House Sparrow, Fork-tailed Drongo, Black Kite, Red-billed Firefinch, Bronze Mannikin, Lilac-breasted Roller, Purple-banded Sunbird, Ring-necked Dove, African Black-headed Oriole, and Feral Pigeon were negatively associated with axis 1.

The distribution of birds was negatively influenced with the coverage of building, pavements, and numbers of parked vehicles and pedestrian.

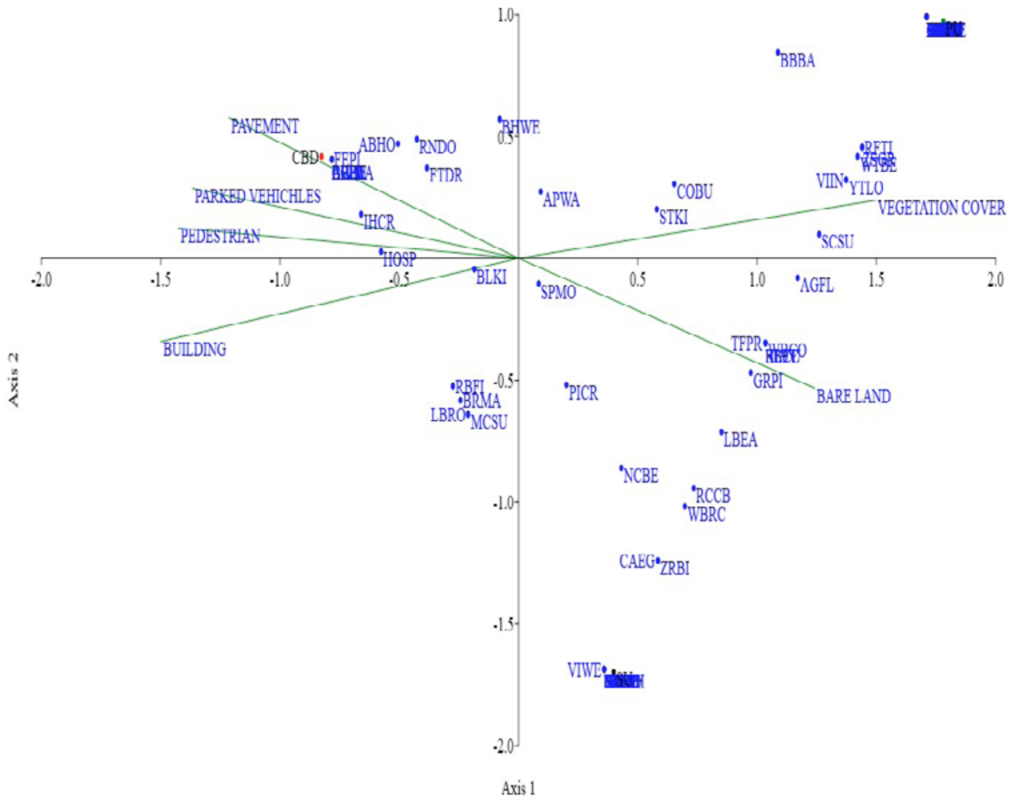

Figure 2: Ordination diagram of canonical correspondence analysis showing the influence of the urbanisation indices on the abundance and distribution of birds in Tanga metropolitan areas. The codes for bird names (4 letters) used in this figure follow the standard abbreviations for common names detailed in Klimkiewicz and Robbins (1978).

DISCUSSION

Bird species diversity

Results for this study showed that assemblages of birds decreased with urbanisation levels. This pattern has been reported elsewhere for birds: Tennessee, USA (McKinney, 2008, Reis at al., 2012, Morogoro (Rija et al., 2014) and Dar es Salaam (John & Kagembe, 2022). The CBD bird assemblages were dominated by alien (non-native) bird species; House Crow and House Sparrow. The two species have adapted to live in the city and have the ability to exploit human resources and tolerate disturbance. Scholars (see Devictor et al., 2007, John & Kagembe, 2022) have shown that highly developed areas such as urban settings host a low diversity of avian communities with high abundance of nonnative species. The lower coverage of vegetation in the CBD zone partly explains the lower species diversity. Urbanisation alters habitat quality and availability, reduces vegetation cover, increases noise and light pollution, and introduces novel predators and competitors. In addition, urban habitats encourage human commensal bird populations in cities and their surroundings; however, the urbanisation process, like landscape conversion, is a great threat to the native bird population. The growing human population and rapid landscape transformation for urban uses threaten avifauna and their associated habitats. Moreover, these changes affect different bird species in different ways, depending on their ecological requirements and adaptations (MacGregor-Fors & Schondube, 2011). On the other hand, the SU and PU had almost the same bird communities supporting relatively high diversity of bird species due to the presence of vegetation and low human disturbances. Farmland, pastureland, in SU and PU areas are important bird habitats as they hold much wildlife outside the protected areas and provide enough resources such as food availability, nesting materials, cover, which are all essential for the birds' survival. Such habitat mosaic discourages establishment of non-native species and provide room or niches supporting co-existence of native species, and thus increasing species diversity.

Level of urbanisation

The urbanisation indices used in this study clearly distinguished the three zones; CBD, SU, and PU. It revealed the complexity that exists within and between localities. There was a gradual change as one moves from CBD through PU. For example, on the Muheza road, immediately after the CBD boundary, there are areas with vegetation cover and scattered buildings. The areas of the vocational training institute, the airport, and Tanga fresh industry, are covered by a significant area of vegetation. Along the Pangani road, there is abruptly changes that are well pronounced. The significant difference in urbanisation levels may indicate that the patterns of development, infrastructure, and population density across the Tanga metropolitan area are somehow similar suggesting that these areas are experiencing high rates of urban growth and transformation. This also suggests that Tanga metropolitan area is experiencing high rates of urban growth and transformation in the level of urbanisation among the studied zones. This has also been reported in Canoas (Brazil) by Meyer (2009) which does not have a clear pattern of urbanisation reflecting the disorganised growth of the city. Despite the existence of core areas with buildings and commercial areas, there are still plots of habitats patchily distributed within the city premises such as gardens and city parks that are present around Tanga metropolitan areas.

Relationship between avian assemblages and urbanisation

The results obtained from this study show that species abundance respond positively towards vegetation and bare land variables that may have been useful for provision of different resources for the birds around the SU and PU. Rija et al (2014) had the same speculations for the bird community in Morogoro urban, Tanzania. The rural zone has more natural vegetation than the urban zones that may have supported birds with food resources such as fruits and insects. On the other hand, high avian abundance in CBD is due to the presence of alien species such as Indian House Crow, House Sparrow and Feral pigeon. The alien species, which have higher abundance in urban areas and are tied in urban and semi urban in their place of origin Emlen (1974). Moreover, in addition to the alien species, birds with high abundances in CBD were generalist species that occupy any areas that retain vegetation cover. Beissinger and Osborne (1982) noted that the urban environments favours species able to utilise small discontinuous patches of vegetation.

CONCLUSION AND RECOMMENDATIONS

The results of this study indicate that bird species diversity increases towards the peri-urban zone, aligning with previous studies conducted in different regions including Tanzania. The CBD exhibited lower species diversity, primarily due to the presence of alien species adapted to urban environments and the scarcity of vegetation cover as compared to SU and PU. The SU and PU areas serve as potential refuges for birds pushed away from the CBD. The findings highlight the importance of preserving green spaces, maintaining vegetation cover, and considering the specific needs of different bird species in urban planning and development strategies. By understanding the complex relationships between urbanisation, environmental variables, and bird populations, authorities can work towards creating more sustainable and ecologically balanced urban environments that support diverse bird communities. Such plans would include managing and controlling populations of alien species, which can negatively affect native bird species. The use of crow traps has worked better in different areas including Tanzania especially in Zanzibar and is less expensive as compared to the use of chemicals, and this method is environmentally friendly. Moreover, House Crow survives mostly on garbage which also need to be managed by the responsible city authorities.

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Appendix 1. The bird checklist recorded in Tanga metropolitan areas and their total abundances

Species	Common name abbreviation	Scientific names	Individuals counted	Relative Species Abundance (%)
Indian House Crow	IHCR	*Corvus splendens*	335	24.67
House Sparrow	HOSP	*Passer domisticus*	227	16.72
Common Bulbul	COBU	*Pycnonotus barbatus*	108	7.95
Black-headed Weaver	BHWE	*Ploceus melanocephalus*	78	5.74
Northern Carmine Bee-eater	NCBE	*Merops nubicus*	70	5.15
Pied Crow	PICR	*Corvus albus*	47	3.46
Speckled Mousebird	SPMO	*Colius striatus*	43	3.17
Fork-tailed Drongo	FTDR	*Dicrurus adsimilis*	37	2.73
Bronze Mannkin	BRMA	*Spermestes cucullate*	36	2.65
Ferral Pigeon	FEPI	*Columba livia*	23	1.69
Vitelline Weaver	VIWE	*Ploceus vitellinus*	23	1.69
Scarlet-chested Sunbird	SCSU	*Chalcomitra senegalensis*	21	1.55
Cattle Egret	CAEG	*Bubulcus ibis*	18	1.33
Red-cheeked Cordon Bleu	RCCB	*Uraeginthus bengalus*	18	1.33
White-throated Bee-eater	WTBE	*Merops albicollis*	14	1.03
Yellow-rumped Seedeater	YRSE	*Selinus reichenowi*	14	1.03
Lilac-breasted Roller	LBRO	*Coracias caudatus*	12	0.88
Tawny-flanked Prinia	TFPR	*Prinia subflava*	12	0.88
Zanzibar Red Bishop	ZRBI	*Euplectes nigroventris*	12	0.88
Grassland Pipit	GRPI	*Anthus cinnamomeus*	11	0.81
Little Bee-eater	LBEA	*Merops pusillus*	11	0.81
African Grey Flycatcher	AGFL	*Malaenornis microrhynchus*	10	0.74
African Black-headed Oriole	ABHO	*Oriolus larvatus*	9	0.66
Red-billed Firefinch	RBFI	*Lagonosticta senegala*	9	0.66
Striped Kingfisher	STKI	*Halcyon chelicuti*	9	0.66
Black Kite	BLKI	*Milvus migrans*	8	0.59
Brown-breasted Barbet	BBBA	*Lybius melanopterus*	8	0.59
Emerald-spotted Wood-Dove	ESWD	*Turtur chalcospilos*	8	0.59
African Pied Wagtail	APWA	*Motacilla aguimp*	7	0.52
Grey-headed Sparrow	GHSP	*Passer griseus*	7	0.52
Ring-necked Dove	RNDO	*Streptopelia capicola*	7	0.52
Collared Sunbird	COSU	*Pycnonotus barbatus*	6	0.44
Pale Batis	PABA	*Batis soror*	6	0.44
D’Arnauds Barbet	DABA	*Trachyphonus darnaudii*	5	0.37
Red-fronted Tinkerbird	RFTI	*Pogoniulus pusillus*	5	0.37
Zanzibar Sombre Greenbul	ZSGR	*Andropadus importunes*	5	0.37

Species	Common name abbreviation	Scientific names	Individuals counted	Relative Species Abundance (%)
Common Fiscal	COFI	*Lanius cabanisi*	4	0.29
Purple-banded Sunbird	PBSU	*Cinnyris bifasciatus*	4	0.29
Village Indigobird	VIIN	*Vidua chalybeate*	4	0.29
White-browed Robin-chat	WBRC	*Cossypha heuglini*	4	0.29
Yellow-throated Longclaw	YTLO	*Macronyx croceus*	4	0.29
Amethyst Sunbird	AMSU	*Chalcomitra amethystine*	3	0.22
Black-and-White Mannikin	BWMA	*Spermestes bicolor*	3	0.22
Bleating Camaroptera	BLCA	*Camaroptera branchyura*	3	0.22
Cinnamon-chested Bee-eater	CCBE	*Merops oreobates*	3	0.22
Mouse-coloured Sunbird	MCSU	*Cyanomitra veroxii*	3	0.22
Northern Brownbul	NOBR	*Phyllastrephus strepitans*	3	0.22
Red-faced Crombec	RFCR	*Sylvietta whytii*	3	0.22
Black-crowned Tchagra	BCTC	*Tchagra senegalus*	2	0.15
Black-headed Heron	BHHE	*Ardea melenocephala*	2	0.15
Black-backed Puffback	BBPU	*Dryoscopus cubla*	2	0.15
European Roller	EURO	*Coracias garrulus*	2	0.15
Klaas's Cuckoo	KLCU	*Chrysococcyx klaas*	2	0.15
Spotted Palm Thrush	SPTH	*Cichladusa guttata*	2	0.15
Trumpeter Hornbill	TRHO	*Bycanistes buccinator*	2	0.15
White-browed Coucal	WBCO	*Centropus superciliosus*	2	0.15
White-browed Scrub-robin	WBSR	*Cercotrichas leucophrys*	2	0.15
Yellow-fronted Canary	YFCA	*Crithagra mozambica*	2	0.15
African Paradise Flycatcher	APFL	*Terpsiphone viridis*	1	0.07
Brown-hooded Kingfisher	BHKI	*Hylcyon albiventris*	1	0.07
Golden Pipit	GOPI	*Tmetothylacus tenellus*	1	0.07
Green-winged Pytilia	GWPY	*Pytilia melba*	1	0.07
Grey-headed kingfisher	GHKI	*Halcyon leucocephala*	1	0.07
Grey-headed Bushshrike	GHBU	*Malaconotus blanchoti*	1	0.07
Hadada Ibis	HAIB	*Bostrychia hagedash*	1	0.07
Lesser Masked Weaver	LMWE	*Ploceus intermedius*	1	0.07
Namaqua Dove	NADO	*Oena capensis*	1	0.07
Northern Wheatear	NOWH	*Oenanthe oenanthe*	1	0.07
Palm-nut Vulture	PNVU	*Gypohierax angolensis*	1	0.07
Sacred Ibis	SAIB	*Threskiornis aethiopicus*	1	0.07
Tropical Boubou	TRBO	*Laniarius major*	1	0.07
Violet-backed Starling	VBST	*Cinnyricinclus leucogaster*	1	0.07

EXPERIENCES, ENJOYMENT AND NOVELTY IN NATIONAL PARKS: CASE OF NYERERE NATIONAL PARK IN TANZANIA

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ABSTRACT

Tourism development involves improvements of national parks. However, more research is needed to assist in further development of national parks particularly understanding experiences, enjoyment and novelty aspects of tourists visiting national parks. Therefore, this paper examines experiences, enjoyment and novelty in national parks with a specific objective of analysing the moderating effect of novelty on indirect experiences and enjoyment of southern national parks among domestic tourists using both quantitative and qualitative methods of data collection. Partial Least Square Structural Equation Modelling (PLS-SEM) and content analysis were used to analyse data from a sample size of 360 domestic tourists. The findings reveal that there is a moderation effect of novelty on the relationship between indirect experiences and enjoyment of national parks among domestic tourists. The study concluded that novelty in terms of change of routine involving “unique”, “different from previous experiences”, and “experienced something new” have a significant moderating effect on the relationship between indirect experiences and enjoyment of southern national parks.

Keywords: enjoyment, experiences, national parks, novelty, Tanzania

INTRODUCTION

Background

National Parks are commonly considered as categories of protected areas in Tanzania. According to Tanzania National Parks (TANAPA), Nyerere National Park which was established in 2019 with a total size of 30,893 sq kms is considered as the largest national park in the country and in Africa (TANAPA, 2023). National parks are among attractions visited by tourists both internationally and domestically. However, due to the Coronavirus disease 2019 (COVID-19) global pandemic, there was loss of USD 4.5 trillion globally for the travel and tourism sector in 2020 (WTTC, 2021). As a result of various measures such as travel bans due to the pandemic, the UNWTO (2021) advocated for reliance on domestic tourism for economic recovery. Although the international tourist arrivals worldwide indicated 80% of the pre-pandemic levels for first quarter of 2023, there are challenges like staff shortage (UNWTO, 2023). This shows that the international tourist arrivals for the tourism industry around the world is recovering but at a slow pace. This is a challenge which implies that for countries such as Tanzania, efforts are still needed to promote domestic tourism including visits to national parks so that more Tanzanians can enjoy national parks.

On the other hand, experiences and enjoyment in tourism have been studied in the past. Previous scholars mentioned that indirect experiences can be obtained from advertising exposure (Xu & Chan, 2009). Additionally, in exploring enjoyment, Mitas and Bastiaansen (2018) adopted Cohen's theory called types of tourists and argued that novelty is a mechanism of tourists' enjoyment. The findings from Mitas and Bastiaansen (2018) indicated that novelty mediates experiences and emotions. Therefore, this is fundamental information in tourism experiences. Although there is increasing numbers of national parks in Tanzania from 16 national parks in 2018 to 22 national parks in 2019, there are limited studies on experiences and enjoyment of national parks by domestic tourists particularly for southern national parks. In general, past studies within and outside Tanzania have focused on tourism issues related to machine learning techniques, motivation, satisfaction, and loyalty (Abdou et al., 2022; Kara & Mkwizu, 2020).

Likewise, Kang et al. (2019) explored enjoyment by examining the influence of leisure and travel experiences on enjoyment with findings indicating that frequency of family and group trips had a positive impact on Korean school adolescents' enjoyment. Therefore, Kang et al. (2019) that that increased numbers of national parks in Tanzania for visitors to explore, and limited literature on the phenomenon of enjoyment of national parks is what motivated this study to examine the moderating effect of novelty on experiences and enjoyment of national parks from the perspective of domestic tourists' views. Hence, in contributing to expand literature on enjoyment in tourism guided by types of tourists' theory, this study examined the moderating effect of novelty on experiences and enjoyment of southern national parks among domestic tourists in Tanzania.

Problem gap for experiences, enjoyment and novelty in national parks

Tanzania has increased numbers of national parks for purposes of visitors to enjoy tourism and boasts a total of 22 national parks including the established national parks such as Nyerere National Park in 2019. However, there are limited studies on enjoyment of national parks in Tanzania despite the existence of many national parks within the country, therefore, this is a challenge. Past studies such as Abdou et al. (2022), Matolo et al. (2021), and Tang et al. (2022) have concentrated on issues of satisfaction, learning techniques and online reviews while there is limited literature on enjoyment of national parks by domestic tourists. However, Kang et al. (2019) explored enjoyment in tourism with a focus on adolescents in schools but not domestic tourists. Equally, Mitas and Bastiaansen (2018) examined enjoyment by using novelty as a mediator of experiences and emotions. Therefore, to bridge the knowledge gap on enjoyment of national parks, this study examined the experiences, enjoyment and novelty in national parks in understanding domestic tourists' views in the context of Tanzania. The main objective of this study was to examine the experiences, enjoyment and novelty in national parks in understanding domestic tourists' views. This study was guided by the theoretical framework of types of tourists' theory developed by Cohen (1972) which assumes that novelty creates enjoyment by fulfilling the goal of a tourism experience, which is to experience something new and different from everyday life. Hence, the specific objectives are to examine the relationship between indirect experiences and enjoyment of southern national parks among domestic tourists, and to determine the moderating effect of novelty on the relationship between indirect experiences and enjoyment of southern national parks among domestic tourists.

Conceptual Framework

The conceptual framework is guided by types of tourists' theory and empirical literature review. The independent variables (indirect experiences), moderating variable (novelty), dependent variable (enjoyment) as well as the developed hypotheses (H1, and H2) assisted to achieve this study's two objectives. Figure 1 indicates the relationship between indirect experiences and enjoyment of southern national parks among domestic tourists (HI) as well as applying novelty as the moderator of the relationship between indirect experiences and enjoyment of southern national parks among domestic tourists (H2).

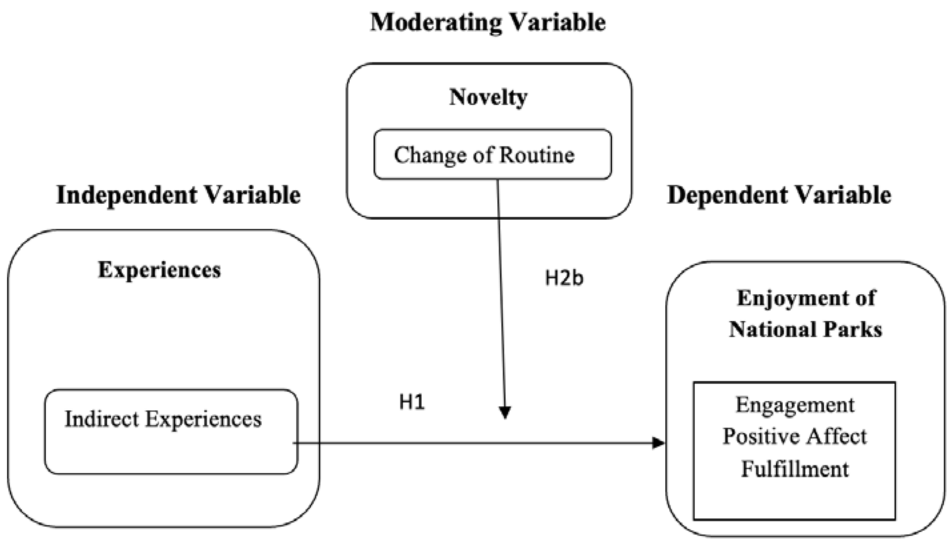

Fig. 1. Conceptual Framework
Source: Compiled by Author from theoretical and empirical literature review

Methodology

The qualitative method through interviews (face to face) with domestic tourists supplemented and validated the quantitative results of objective 1 and objective 2. The selection of **Nyerere National Park** was due to its tourism potential, and being the largest national park in Tanzania as well as in Africa spreading over the regions of Morogoro, Iringa, Pwani, Lindi, Mtwara and Ruvuma as in Figure 2.

Fig. 2 Location of Nyerere National Park in Tanzania

Source Adapted from Tanzania Regions Map (2021), Essential Destinations (2021)

Research Design and Targeted Population

This study opted for a cross-sectional design by collecting data from domestic tourists using survey strategy and face to face interviews only once in order to understand the phenomenon of enjoyment of national parks within the context of Tanzania. The target population for this study was tourists who visited Nyerere National Park in Tanzania. As a newly established national park in 2019, Nyerere National Park was elevated from Selous Game Reserve and this study used the population figures from Selous Game Reserve as a guide. The Ministry of Natural Resources and Tourism (MNRT) indicated that there were 22,964 tourists (international and domestic) that visited Selous Game Reserve in 2017 (MNRT, 2017). Therefore, the target population was 22,964 tourists.

Sampling Techniques, Sampling Frame and Sample Size

This study probability sampling (simple random probability) due to its non-biased nature and non-probability sampling (convenience sampling) for non-random criteria of case study for the sample of domestic tourists. While accessing respondents at the gate entry point using convenience sampling, this study adhered to the availability as well as the willingness of the respondents. Therefore, the collected qualitative data of this study reached a saturation level of 21 domestic tourists and that any further collection of data from the interviewed respondents would not have emerged new themes. Sampling frame is domestic tourists as the unit of analysis drawn from the target population of 22,964 tourists of which there were 6142 domestic tourists. Hence, the sample frame for this study was

6142 domestic tourists. The sample size for this study was guided by the sample size table developed by Krejcie and Morgan (1970). Therefore, the sample size for this study was obtained from the sample frame of 6142 domestic tourists hence the sample size was 361 domestic tourists. Furthermore, Mathers et al. (2000) advised to add 5% on sample size to account for low response rate. This study added 5% to the sample size 361 hence the sample size was 380.

Data Collection and Instruments

Data collection was done concurrently with two phases whereby one phase conformed with the quantitative approach which involved survey questionnaires handed to domestic tourists. Another phase involved in-depth interviews with domestic tourists so as to obtain qualitative information on novelty, experiences and enjoyment of national parks among the domestic tourists to supplement the quantitative findings. The quantitative phase was conducted in the month of July 2021 to June 2022 while the qualitative phase using checklist of question as interview guide was done in August 2021 to June 2022. Prior to actual field data collection, a pilot study was carried out at Mikumi National Park which was chosen due to its proximity to Nyerere National Park. The pilot study which involved pre-test of the survey questionnaire to 50 domestic tourists at Mikumi National Park ensured the items in the questionnaire were accurate, clearly understood by respondents and measured the intended objectives of this study.

To further improve the face validity of the data collection instrument for this study, tourism experts were consulted to confirm the accuracy of the items in the survey questionnaire in terms of the overall format but also the content and sequencing of words. Furthermore, the designed survey questionnaire reflected 20 statements which are non-numerical using the scaling method of 5-point Likert-scale type. Due to the nature of this study having respondents as domestic tourists in the national park, this study adopted 5-point Likert-scale with strongly disagree (1) and strongly agree (5) from previous empirical studies in tourism such as Mkwizu (2018). The application of 5-point Likert scale increases the response rate and quality as well as reduces respondents' frustration level (Babakus & Mangold, 1992). Statements for experiences, novelty and enjoyment were adapted from past studies including Curtis and Davidson (2013), Lin et al. (2008), Mak (2015) and Kim (2009). Similarly, the demographic variables were adopted from Mkwizu (2018).

Data Analysis

The adoption of the descriptive statistics analysis using Statistical Package for Social Sciences (SPSS) version 25 provided frequencies and percentages of the respondents' sample characteristics. Partial Least Square Structural Equation Modelling (PLS-SEM) was used for moderation analysis (Ringle et al., 2015). Due to testing the moderation effect then this study used PLS-SEM. However, testing for convergent validity using Average Variance Extracted (AVE) and multicollinearity was done to ensure the measurement model evaluation using Confirmatory Composite Analysis (CCA) for formative measure is considered as indicated in Hair et al. (2020). Qualitative data collected from the face to face interviews with the respondents was analysed using content analysis.

Validity and Reliability

In order to ascertain coverage of data collection instrument and face validity of respondents, this study used a pilot study approach prior to the survey. Pilot study involved tourism experts who assisted to test the content, wording, sequence and format for face validity of the suggested items while pretest of the survey questionnaire with 50 domestic tourists at Mikumi National Park helped to gather the necessary opinions on suitability of the questionnaire items. This study used both tourism experts and pilot study to ensure the validity of the questionnaire prior to actual data collection.

In this study, the independent variable (experiences) revealed a construct validity of 0.798, the dependent variable (enjoyment of national parks) had 0.692 and the moderating variable (novelty) was 0.796. According to Hair et al. (2020), the composite reliability value that is deemed acceptable should measure reliability value of 0.70 and above to indicate that the questions are reliable. In this study, the internal consistency of the constructs using composite reliability indicated that independent variable (experiences) had 0.922, the dependent variable (enjoyment of national parks) was 0.914 and the moderating variable (novelty) was 0.877.

RESULTS

Summary of characteristics of the sampled respondents revealed that nearly half of the respondents were aged between 26 to 35 years (40.8%). Over half of the respondents were from Dar es Salaam (54.7%) with income above 300,000 TZS (48.6%) and are males (60.8%). Further findings indicated that the majority of the domestic tourists have university education (38.6%) characterised as first-time visitors to Nyerere National Park mostly by package tour (58.9%) and concentrated more on the wildlife safari activity (90%).

The bootstrapping tested the relationship between indirect experiences and enjoyment of southern national parks with significance level of 0.05. The findings revealed that Hypothesis (H1) has a significant relationship between indirect experiences and enjoyment of southern national parks (p=0.000). Figure 3 shows the estimate model of the tested relationships which means that the indicators of EXP7 to EXP9 for indirect experiences have a significant relationship with the indicators of ENJ1 to ENJ6 for enjoyment (engagement, positive affect and fulfilment) of southern national parks among the domestic tourists who visited Nyerere National Park. So, H1 is accepted.

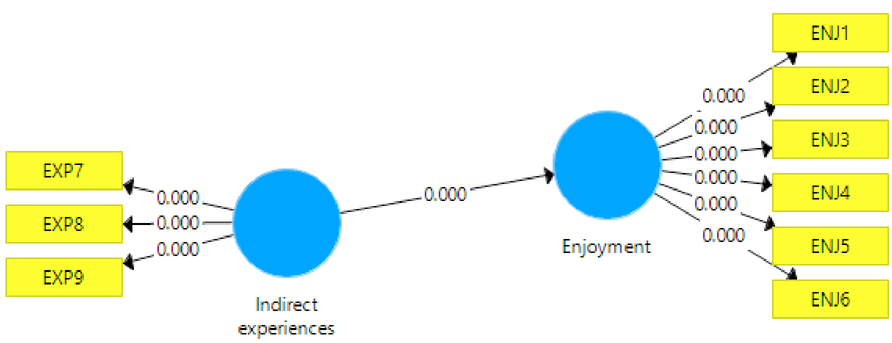

Fig. 3 Indirect experiences and enjoyment of national parks

The moderation effect of novelty on indirect experiences and enjoyment of southern national parks with significance level of 0.05 was tested and the estimation model is indicated in Figure 4. The findings reflected a moderating effect which is significant for novelty on the relationship between indirect experiences and enjoyment of southern national parks with T value (6.451), p value (0.000) and path coefficient as -0.249. These findings suggest that the moderation effect is significant but also with a negative path coefficient which further implies that novelty is significant and at the same time it does weaken the relationship between indirect experiences and enjoyment of southern national parks among domestic tourists. This implies that the hypothesis H2 is accepted due to the significant moderation effect.

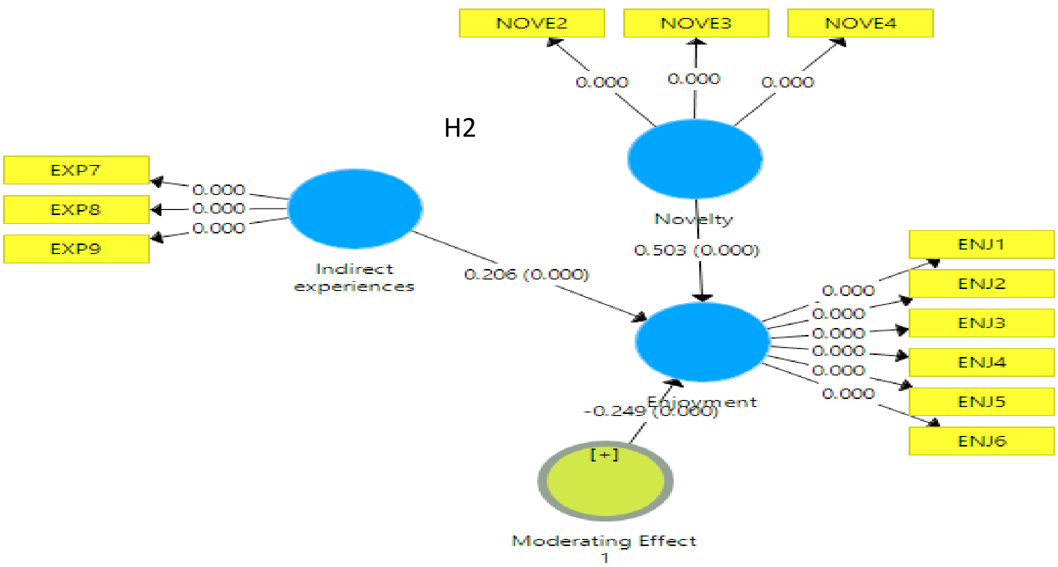

Fig. 4 Moderation of novelty on indirect experiences and enjoyment (H2)

The relevant interview results from domestic tourists are revealed in the discussion section as quotations in order to support the quantitative findings due to this study's approach of using both quantitative and qualitative methods.

DISCUSSION

The findings on characteristics of the respondents implied that the bulk of domestic tourists that visited Nyerere National Park were mostly university educated males from Dar es Salaam with income above 300,000 TZS and were first-time visitors on package tours having a wildlife safari as their preference of activity in the national park. Nyerere National Park is a newly established national park and therefore, the findings have shown that most of these domestic tourists are first time visitors and therefore, they are unfamiliar to the park and its activities as supported by one of the interviewed domestic tourists who said that;

> *"This is my **first time to visit** Nyerere National Park ...and I have **enjoyed** the park and its wildlife"(Nyerere National Park, Female, age group 26 to 35 years old)*

Guided by Cohen's category of tourists, this implies that these domestic tourists are seeking familiarity of the park since they are unfamiliar with the park and its activities due to them being first time visitors. However, some of the first-time visitors have also been to other national parks as reported by one of the interviewed domestic tourists;

> *"I have visited Mikumi National Park but I must say **Nyerere National Park is huge and the game drive was pleasant**" (Nyerere National Park, Female, age group 36 to 45 years old)*

Most of these domestic tourists are also visiting the park on package tours meaning that they are visiting on pre-determined itinerary hence guided by Cohen's category definition of organised mass tourists, these domestic tourists can be categorised as organised mass tourists who seek familiarity rather than novelty. The findings of domestic tourists' characteristics of this study differ from previous studies like Blomstervik et al. (2020) done in Portugal. The variations in results are due to context differences. The unit of analysis for this study concentrated on domestic tourists only as the scope of the study while Blomstervik et al. (2020) included international and domestic tourists whom the majority were characterised as university educated females. Furthermore, the domestic tourists of this study were university educated males and therefore, different results from the findings of domestic tourists by Blomstervik et al. (2020).

The significant results are in line with Mkwizu (2018) and this is because of television exposure is still dominating as a source of information among domestic tourists. But results are not in line with Sama (2019) which was dominated by print media. Furthermore, the indicators in this study for indirect experiences were "Exposure to radio advertising about activities of the national park (EXP7)", "Exposure to social media advertising about activities of the national park (EXP8)", and "Exposure to television advertising about activities of the national park (EXP9)" that are related to indicators of enjoyment (engagement, positive affect and fulfilment) of southern national parks in terms of "During the activity I was deeply engrossed (ENJ1)", "During the activity I concentrated fully (ENJ2)", "During the activity I felt happy (ENJ3)", "During the activity I felt content (ENJ4)", "The activity was worthwhile (ENJ5)", and "The activity was fulfilling (ENJ6)". For indirect experiences, one interviewed domestic tourist stated that:

> *"I have watched this national park on television but I feel that a lot needs to be done on **advertising as well as branding the Nyerere National Park**" (Nyerere National Park, Female, age group 36 to 45 years old)*

Additionally, the significant results on the relationship between indirect experiences and enjoyment of southern national parks support the use of types of tourists' theory to guide the analysis of indirect experiences and enjoyment of southern national parks in the context of Nyerere National Pak in Tanzania. Equally, the characteristics of the sampled domestic tourists also showed that they are first time visitors under package arrangements meaning that they have used organized tour operators. Another interviewed domestic tourist enjoyed and related to Tanzania Royal Tour by adding that;

> *"I love and **enjoy** the wildlife. Being a tour guide was my old profession. So, I naturally visit national parks as a hobby. In fact, it is great that the **Tanzania Royal Tour** has been launched and I watched the film which I think….is a great way to attract more visitors to the park" (Nyerere National Park, Male, age group 36 to 35 years old)*

Furthermore, the indicators of novelty measured using change of routine that weakens the relationship between indirect experiences and enjoyment of southern national park are unique (NOVE2), different from previous experiences (NOVE3) and experienced something new (NOVE4). This study's results on novelty measured using change of routine as a moderator with significant effect on indirect experiences and enjoyment of southern national parks is different from Blomstervik et al. (2020). The differences of results are attributed to geographical locations so it is context-based but also methodological since the operationalisation of the measurement for novelty was measured using change of routine. Additionally, some of the interviewed domestic tourists may supplement this information whereby one of the domestic tourists mentioned that;

> *"For me, it is a way of **relaxing my mind**. You know women, we have a lot of chores at home. So, it is nice to visit national parks more often as a relaxation but also **to change environment**" (Nyerere National Park, Female, age group 36 to 45 years old)*

Equally, some of the interviewed domestic tourists may also supplement information as to why the moderating effect of novelty weakens the relationship of indirect experiences and enjoyment of southern national parks. A domestic tourist noted that;

> *"No I did not fully enjoy my tour because our tour guide was not able to communicate effectively when our car broke down. So, we did not finish the tour as we had expected because **it took long for the tour guide to help. Communication is important**" (Nyerere National Park, Male, age group 18 to 25 years old)*

Responses from domestic tourists revealed that change of routine in terms of unique, different from previous experiences and experienced something new weakens the indirect experiences and enjoyment of southern national parks relationship due to poor communication within the park which signals the need to improve communication and avoid tour guides from experiencing communication problems and failing to serve the domestic tourists better but also due to communication failure, the domestic tourists did not fully enjoy the rest of their tour as the car broke down and help delayed.

In concluding the discussion, the significant findings on the moderation effect of novelty on the relationship between indirect experiences and enjoyment of southern national parks supports the application of types of tourists' theory in the context of Tanzania by validating the types of tourists' theory through the inclusion of the demographic information whereby the type of domestic tourists who visited Nyerere National Park are characterised as university educated males with income above 300,000 TZS and first-time visitors on package tours having a wildlife safari. In addition, this indicates that as first-time visitors they have no familiarity with national park and its activities other than exposure to television advertising. But at the same time, the domestic tourists are visiting on package tours meaning they are organised mass tourists and their preference was wildlife safaris compared to other activities such as walking safari, boat ride, bird watching or fly-camping. These organised mass tourists according Cohen's typology prefer familiarity the most and the least about novelty which could perhaps explain the weakening of novelty on the relationship between indirect experiences and enjoyment of southern national parks among the domestic tourists.

Significance and contribution of this study

This study has significance by contributing new knowledge from the perspective of Tanzania on how novelty moderates the relationship between indirect experiences and enjoyment of national parks among domestic tourists. Further, the use of the concepts of novelty, indirect experiences and enjoyment of national parks provides the conceptual contribution of this study. From the theoretical perspective, this study has shown that novelty significantly moderates the relationship between indirect experiences and enjoyment of national parks among domestic tourists. Additionally, for the deficiencies of the types of tourists' theory of not including demographic information, the findings of this study indicated that adding demographic information as well as other types of information like first-time visitor or repeat visitor and activity preference is crucial in categorising the type of domestic tourists in the context of Tanzania. Thus, the theoretical and contextual contribution. Another significance of this study is the practical contribution in guiding tourism stakeholders like marketing organisations or companies and tour operators as well as the tourism authorities such as MNRT and TANAPA on novelty, experiences and enjoyment of national parks by domestic tourists.

Also, policy and decision makers in the tourism sector will be able to use the outcome of this research in improving promotion policies and strategies in the tourism industry such as the Tanzania's National Five-Year Development Plan 2021/22-2025/26 under subsection of the tourism sector. Additionally, the focus on domestic tourism in this research is key and critical as well as in line with UNWTO (2023) which emphasised on capitalising domestic tourism as an alternative to economic recovery for many nations around the world and Tanzania is no exception. The combination of the unit of analysis (domestic tourists), mixed methods approach, application of PLS-SEM and content analysis avails the methodological contribution of this study which has significance as database of future studies. Hence, other researchers around the world may also use the results of this study for comparison purposes when building further knowledge on the phenomenon of enjoyment of national parks among domestic tourists.

RECOMMENDATIONS

The government, the private sector and tourism stakeholders should improve the infrastructure and communication systems in southern national parks particularly in Nyerere National Park which has shown to have poor communication infrastructure which leads to poor services amongst tour guides employed by tour operators. For domestic tourists seeking novelty through changing routine of their activities by visiting national parks wish to see improved roads and other services including tour guides with great knowledge about wildlife and story-telling skills. Again, the tourism stakeholders such as wildlife training institutions can improve their tour guide training programs so that the tour guides are knowledgeable and competent.

Some of the domestic tourists wished to see more advertising of Nyerere National Park. Hence, this study recommends that the government and the private sector should join hands and invest in preparing TV programs that show case the beauty of Nyerere National Park since it is still relatively new to the public due to its establishment at the level of a national park status from a game reserve only in 2019. Now being the year 2023, it is five years since its establishment and therefore, more efforts in terms of advertising and branding is needed so that novelty can strengthen the relationship between indirect experiences and enjoyment of southern national parks among domestic tourists rather than weaken the relationship as evidenced in this study's moderation effect results.

Direction for Future Studies

Future studies may explore longitudinal design to understand the patterns of domestic tourists in relation to experiences and enjoyment of national parks so as to boost domestic tourism in Tanzania. For methodological advancement, future studies may sample international tourists to explore enjoyment of national parks. Other researchers may explore the mediating effect of novelty on experiences and enjoyment of national parks. The emerged themes from the qualitative approach can be utilised for quantitative analysis for future studies.

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THE IMPACT OF COMPOSTING BEHAVIOUR CHANGE CAMPAIGN FOR SAVING CHIMPANZEES IN WESTERN TANZANIA THROUGH THE TACARE MODEL

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ABSTRACT

Smallholder agriculture ranks as the prime threat to chimpanzees' habitat in Tanzania, followed by conversion of land to settlement and infrastructure, anthropogenic diseases, and many more other threats (TAWIRI, 2018). In line to the prime threat, however, emerging debates on forest loss in Western Tanzania are currently pivoted around rapid population growth acerbated by high fertility rate (Kigoma with 17.2% and Katavi 34.4%) of teen pregnancy rate as compared to 22.7% of the national average (THDS 2022); and migration of people and livestock driven by climate change. To respond to some of the threats affecting chimpanzees and their habitats in the Gombe Masito Ugalla Landscape, the Jane Goodall Institute, through the USAID-funded Landscape Conservation in Western Tanzania Project piloted a Social and Behaviour Change Campaign, grounded on a composting program to support communities to improve soil fertility to boost food security and family incomes to help people understand the connection between the farm, soil and habitat conservation. Crucial to the success of agricultural projects under TACARE has been the participation of women, as they are the ones who care for the kids, farms, and households and are also seriously affected by the destruction of the environment (Kashula, 2022). The compost program is implemented using the Lake Tanganyika Catchment Reforestation and Education (TACARE) model to achieve its data-driven outcomes since 2020 to date. This paper explores how the Composting Social Behaviour Change Campaign blended the TACARE approach (Engage, Listen, Understand, Facilitate and Step-back) to empower communities in Kigoma and Katavi regions to deepen their knowledge and understanding of the JGI's community-led conservation approach to shape their perceptions and behaviours of sustainable use of land and forest resources to save the chimpanzees' communities in the landscape. The father of TACARE admits that the TACARE approach intertwines LePSA methods of introducing project activities in its approach: Learner-centred (Le) training: Problem Solving (P); Self-discovery (S) and Action (A) (Strunden, 2022). The paper also pulls some interesting cases from individuals, power couples and communities positively impacted by the campaign to draw a learning curve of the behavioural change intervention for the conservation in Western Tanzania.

Keywords: Behaviour, Change, Community, Conservation, Chimpanzees, Composting

INTRODUCTION

Smallholder agriculture, particularly subsistence farming, is a significant threat to chimpanzee conservation in Western Tanzania. This practice leads to habitat loss, fragmentation, and degradation, compounded by settlement expansion, infrastructure development, logging, and other anthropogenic pressures (TAWIRI, 2018-2023). Rapid population growth, driven by high fertility rates in Kigoma (17.2%) and Katavi (34.4%), as well as climate change-induced migration, exacerbates these issues (THDS, 2022). The presence of over 300,000 refugees from Burundi and the Democratic Republic of Congo, who have relied on forest resources for building materials, firewood, and bush meat, further threatens chimpanzee habitats (TAWIRI, 2018). Historical policies, such as the Ujamaa period's collectivist agriculture approach, also contributed to forest conversion and habitat loss (Strunden, 2022).

This paper evaluates the effectiveness of the Composting Behaviour Change Campaign (BCC), implemented by the Jane Goodall Institute through the USAID Landscape Conservation in Western Tanzania project, in reducing shifting cultivation in critical chimpanzee habitats. The aim is to assess how the BCC, utilizing the TACARE model, has influenced farmers' practices and contributed to chimpanzee conservation by improving food security and income in Kigoma and Katavi. The hypothesis is that the BCC, by integrating TACARE's components—Engage, Listen, Understand, Facilitate, and Step-back—has successfully empowered communities to adopt sustainable land-use practices, thereby enhancing conservation outcomes. The paper also presents case studies of individuals and communities positively impacted by the campaign, offering insights into the effectiveness of this behavioural change intervention for chimpanzee conservation in Western Tanzania.

Shifting Cultivation: A Prime Threat to Chimpanzee Conservation Globally

Shifting agriculture, commonly known as slash-and-burn farming, is a historically significant practice found in many regions across the globe. This method, which involves clearing land by burning vegetation and then cultivating crops, poses severe threats to chimpanzee habitats and biodiversity through deforestation and land degradation. In response, behaviour change campaigns have been launched to promote composting as a sustainable alternative. This review evaluates the effectiveness of these campaigns in reducing shifting agriculture and supporting community-led wildlife conservation efforts.

Behaviour change campaigns focused on composting have shown notable success in reducing the practice of shifting agriculture. These campaigns have led to significant changes in farmers' attitudes and behaviours regarding land use. For instance, Lopez et al. (2019) reported a considerable decrease in land used for shifting agriculture in a rural community following a composting campaign. This shift was attributed to increased awareness and adoption of composting practices. Similarly, Smith et al. (2020) observed a transition towards more sustainable farming practices, such as composting, resulting in reduced reliance on shifting agriculture.

These studies underscore the potential of behaviour change campaigns to transform agricultural practices. By fostering a shift from slash-and-burn methods to composting, these campaigns contribute to reduced land clearance and promote more sustainable land management practices.

Support for Community-Led Wildlife Conservation Efforts

The shift to composting not only addresses agricultural sustainability but also supports community-led wildlife conservation initiatives. Shifting agriculture often results in deforestation and habitat loss, which adversely affect wildlife populations. Campaigns promoting composting mitigate these effects by decreasing land clearance and preserving natural habitats. Johnson and Lee (2018) demonstrated that the adoption of composting led to increased forest cover and improved habitat quality, which in turn supported greater biodiversity and enhanced wildlife presence in agricultural areas.

This connection highlights the dual benefits of composting: it supports agricultural productivity while also contributing to the conservation of wildlife habitats. By preserving and restoring natural environments, composting practices play a crucial role in supporting biodiversity and conservation efforts.

Challenges and Considerations

Despite the positive outcomes, behaviour change campaigns face several challenges. Cultural and traditional practices related to shifting agriculture can hinder the adoption of new methods. Successful implementation requires a respectful approach that considers local norms, beliefs, and livelihoods (Strunden, 2022). Additionally, the availability and affordability of composting materials and infrastructure can be a barrier, especially in resource-limited areas. Ensuring access to necessary resources and infrastructure is vital for the success of composting initiatives.

Socioeconomic factors also play a critical role in the success of behaviour change campaigns. Economic incentives, market access, and alternative income-generating activities are essential for encouraging farmers to transition from shifting agriculture. Martinez et al. (2021) emphasized the importance of providing training and support for farmers, along with alternative livelihood opportunities such as agroforestry or sustainable farming practices. Addressing these socioeconomic factors is crucial for fostering long-term behaviour change and achieving successful conservation outcomes.

Shifting Cultivation as a Threat to Chimpanzee Conservation in Western Tanzania

In Western Tanzania, shifting cultivation is identified as a primary threat to chimpanzee conservation. Strunden (2022) highlights that the expansion of agricultural land due to population pressures, particularly following the Ujamaa and villagization policies, has led to significant forest loss around Gombe National Park. This conversion of Miombo forests into agricultural land has had detrimental effects on chimpanzee habitats.

Strunden (2022) also notes the challenges in achieving behavioural change in this context, emphasizing the need to understand and address community priorities and needs. The Theory of Reasoned Action (TRA) supports this approach, suggesting that positive attitudes toward conservation can lead to pro-conservation behaviors (Lepp & Holland, 2006). Effective conservation efforts must consider these attitudes and the perceived social pressures influencing behaviour.

Kashula (2022) underscores the importance of involving women in agricultural projects, as they are often most affected by environmental changes and household management. Mjungu (2022) argues that aligning conservation efforts with local needs can enhance community support for forest conservation. By addressing daily needs and providing alternative livelihoods, communities are more likely to support and engage in conservation initiatives.

The Jane Goodall Institute's TACARE Community-Led Conservation Approach

The TACARE Approach (Pintea, L. et al.2023)

The TACARE model, developed by the Jane Goodall Institute (JGI), represents a holistic, community-led approach to conservation. The model emphasizes local ownership and engagement, ensuring that local people and institutions drive conservation and development decisions in their landscapes. The TACARE approach employs the LePSA method—Learner-Centred Training involving Problem-posing, Self-discovery, and Action (Strunden, 2022)—to facilitate effective community involvement and adaptability

Adaptability and pragmatism are central to the TACARE approach. Strunden (2022) highlights that the ability to adjust strategies based on community feedback and environmental changes is crucial. For example, shifting from reforestation to natural forest regeneration and incorporating land use planning have been effective in restoring chimpanzee corridors.

Pintea et al. (2023) describe TACARE as a proven model that integrates conservation with community development. By using high-resolution satellite imagery and incorporating local knowledge, TACARE enhances understanding and collaboration between JGI staff and local communities (Lilian, 2022). This approach acknowledges that conservation is a local, social, and developmental process rather than merely a scientific endeavour.

Kamenya (2022) emphasizes the value of local expertise and academic background in fostering trust and relevance in conservation projects. Local involvement and the integration of local knowledge enhance the effectiveness and sustainability of conservation efforts (Waylen et al., 2009). Kashula (2022) notes that despite scaling up, the core principles of the TACARE approach—engagement, listening, understanding, and facilitation—remain unchanged.

Local and national dialogues are crucial for the success of the TACARE approach. Mtiti (2022) highlights the mutual benefits between TACARE and government policies, which support the implementation of conservation projects. Effective collaboration with regional and national authorities ensures the alignment of conservation strategies with policy frameworks and local needs.

The integration of the TACARE model into behaviour change campaigns, such as those promoting composting, has been instrumental in achieving conservation goals. By applying TACARE principles—Engage, Listen, Understand, Facilitate, and Step Back—the composting behaviour change campaign has successfully addressed community needs while promoting sustainable practices. This approach has been vital in supporting chimpanzee conservation and enhancing biodiversity outcomes in Western Tanzania.

Behaviour change campaigns promoting composting as an alternative to shifting cultivation have demonstrated significant potential in reducing land clearance and supporting community-led wildlife conservation. The TACARE approach, with its emphasis on local engagement and adaptability, has proven effective in integrating conservation with community development. Addressing cultural and socioeconomic challenges through tailored strategies and collaborative efforts is essential for achieving long-term conservation success. Future initiatives should continue to leverage community knowledge, provide necessary resources, and align conservation goals with local needs to enhance both agricultural sustainability and wildlife preservation.

METHODOLOGY

This paper examines the impact of Behaviour Change Campaign (BCC) on forest and chimpanzee conservation in the USAID Landscape Conservation in Western Tanzania Project through a multi-method approach. The methodology integrates data from surveys, focus group discussions, and documented case studies to analyse changes in community perceptions, attitudes, and behaviours. The following outlines the key studies and data collection tools employed in each research:

Socioeconomic Baseline Study (November 2019 - April 2020)

The socioeconomic baseline study provided foundational data for assessing the impact of the BCC campaign. This comprehensive survey utilized a range of data collection tools to capture detailed information on household and individual characteristics. The study included:

- Household Surveys: A total of 838 households were surveyed, comprising 735 households headed by men and 103 by women.
- Individual Surveys: The survey gathered data from 1,325 individuals, including 707 women (household heads or spouses) and 617 men (household heads or spouses).
- Time Allocation Surveys: Conducted with 247 individuals, this component involved 119 women and 128 men, focusing on time spent on various activities.
- Key Informant Interviews: Semi-structured interviews were conducted with 28 village leaders to gain insights into community dynamics and perceptions.

- Focus Group Discussions (FGDs): FGDs were organized on multiple themes, including:
- Behaviour Change and Family Planning: 6 groups of men and 6 groups of women.
- Women Empowerment: 6 groups of men and 6 groups of women.
- Seasonal Calendars: 6 groups of men and 6 groups of women.
- In-Depth Interviews: Lifetime histories, based on Hagemeister's (1992) methodology, were used to understand how historical factors influence current attitudes and behaviours.

Focus Group Discussions (September - October 2020)

Focus group discussions were conducted with 60 participants from pilot villages (Kajeje, Vikonge, and Isubangala). These discussions aimed to assess the community's response to the BCC campaign and gather qualitative insights into changes in attitudes and behaviours.

Post-Pilot BCC Evaluation

This evaluation compared treatment and control villages to assess the impact of the BCC campaign. The evaluation involved:

- Treatment and Control Villages: Three villages were designated as treatment sites and three as control sites.
- Farmer Surveys: A total of 377 farmers were surveyed across both treatment and control villages.
- Interviews and Observations: The evaluation included interviews with 9 lead farmers, the use of observation checklists for 377 subjects, and FGDs with 31 individuals.

Midterm BCC Farmer Evaluation Survey

This survey provided an interim assessment of the BCC campaign's effectiveness. It included:

- Farmer Surveys and Observations: Data were collected from 279 farmers, utilizing observation checklists.
- Focus Group Discussions: Five Focus groups Discussions of seven people each were conducted.
- Key Informant Interviews: Nine interviews were held with key stakeholders.
- Sampling: Farmers were selected from both treatment and control villages, with 55 farmers per treatment village (total n=219) and 30 farmers from randomly selected hamlets in control villages (total n=60).

Field Monitoring and Impact Stories (2021 - 2023)

Regular field monitoring was conducted by the BCC implementation team to observe and record the ongoing impacts of the campaign. This included the documentation of impact stories to provide qualitative evidence of changes in community practices and conservation outcomes.

Data Analysis

The collected data were analysed to evaluate the effectiveness of the BCC campaign in altering perceptions and behaviours related to forest and chimpanzee conservation. Quantitative data from surveys were analysed using statistical methods to identify significant changes and trends. Qualitative data from FGDs, interviews, and field observations were analysed thematically to capture in-depth insights and contextualize the quantitative findings.

This methodology provides a comprehensive assessment of the BCC campaign's impact, combining quantitative and qualitative approaches to evaluate changes in community attitudes and behaviours and their implications for chimpanzees and habitat conservation efforts.

RESULTS

The paper presents three important findings which were key in achieving campaign results in the landscape: i) BCC-Socioeconomic Baseline Survey November 2019-April 2020 ii) BCC Focus Group Discussions (September-October 2020) iii) BCC Post Pilot Survey 2021 and iv) BCC Mid-term Evaluation 2022 and v) BCC Field monitoring observations and recording of stories of impact (2021-2023, pg. 16).

The Socioeconomic Baseline Survey (November 2019-March 2020)

The BCC Baseline Survey (November 2019-March 2020) that was conducted along the socioeconomic baseline survey for the entire project concluded that shifting cultivation was still a major threat to chimpanzee conservation in the Gombe Masito Ugalla landscape thus confirming the Tanzania Chimpanzee Conservation Action Plan (2018-2023)'s national level threat chimpanzee ratings according to 2016 technical workshop, due to its slush and burn nature of farming. The behaviour is exacerbated by rapid population growth due to climate change in other areas of the country which pushed agro-pastoralists from Northwestern part of the country such as Mwanza, Simiyu, Shinyanga, Tabora and Geita to migrate and settle in the landscape. Refugee influxes and illegal migrants from Burundi and DRC as well as teen pregnancy rate have added to the population growth question. The population growth increases the demand for communities to produce more food to feed families and acquire incomes to respond to some family needs. Although other behaviours were equally dangerous as shifting cultivation, shifting cultivation was more hazardous to chimpanzees' conservation in the landscape compared to illegal livestock incursion, illegal charcoal burning, illegal logging and illegal settlements in the chimpanzee's conservation miombo woodlands.

The socio-economic baseline survey cites that "moreover, soil degradation is contributing to increased demand for fertile land. In villages in Zone 1 villages, focus group discussion (FGD) participants said people were willing to risk paying high fines and potential arrests to gain access to the more fertile soil. If a household cultivates the land for too long, the next generation of farmers often seeks more fertile ground in the forests. People in other zones also mentioned the problem of poor fertility of their village land, particularly in the refugee areas (Zone 4). Focus group discussion participants said the soil is infertile because they have been cultivating the same plots for several decades. In comparison to other zones, more households in this zone indicated they rely on chemical fertilizer to improve soil fertility. Consequently, they requested new, more productive land for farming.

Focus Group Discussions (September-October 2020)

A focus group discussion conducted in three pilot villages in the landscape, namely, Isubangala, Kajeje and Vikonge as from September-October 2020 confirmed that farmers farm in the forest due to loss of soil fertility in the farms that are close to their homes. According to farmers this happens because, the fertile soils in miombo woodlands are not deep enough to sustain agriculture for a long period of time thus creating some demand for opening new farms in the virgin forests especially along the riverine, thus encroaching key chimpanzee habitats. The focus group discussion also revealed although some farmers were quite knowledgeable on and applied industrial chemical fertilizers and its effects on the soils, farmers demonstrated scarce knowledge of organic fertilizers, such as compost. However, they showed readiness to know the technology and use it to revive farms' productivity to boot agricultural yields to sustain family livelihoods.

Post Pilot BCC Evaluation Survey (May 2021)

The data collection tools used in this study were individual farmer survey and observation checklist which engaged 377 subjects, lead farmers interviews that engaged nine (9) subjects and Focus Group Discussions which engaged 31 individuals. The survey findings revealed that most farmers in the post pilot villages plant three (3)-Six (6) acres mostly cultivating annual crops. Trained farmers saw greater yields than non-trained farmers. While trained farmers harvested an average of 9.3 and 10.91 sacks of maize and beans respectively, untrained farmers harvested 8.6 and 6.9 sacks of maize and beans respectively. The study further revealed that most farmers do not own livestock, which has been cited as a problem in accessing manure. The study further revealed that children help with farming, primarily with harvesting, processing, and ploughing, however data collection team didn't see children participating in composting during observation.

The study demonstrated that pests and soil fertility were cited as severe problems for farmers. While 42% of farmers said that they have not heard of people farming in the forests, 84% of trained farmers and 68% of untrained farmers said people farm in forests for more fertile soil. Village leaders said most people know the benefits that forests provide. "People run to the forests in search of healthy soil for agricultural productivity. They move to such areas seasonally since they have family in the village," as one of the village leaders was quoted during the in-depth interviews. In addition, village leaders stated that forest encroachment is a serious threat due to shortage of land, soil fertility loss and access to water for irrigation, better grazing and farmland negatively impacted by climate change and low capacity to protect these areas. Village leaders revealed further that soil fertility is a major problem, and little is being done about it. The provided reasons for soil fertility loss as over cultivation, soil erosion, shifting cultivation by those with large farms, lack of mechanization keeps average farm size small below three (3) acres etc. The study also revealed that most farmers 54% are fertilizing their soil, mostly with chemical fertilizers. Compost training came too late and compost was not sufficient. They were influenced to use chemical fertilizers most often by friends and family. JGI was the primary influence for using compost fertilizer. Farmers in Isubangala produced most piles compared to Vikonge and Kajeje. Most piles were above ground with a structure or shade tree covering it close to home. Everyone that tried it (n=98) said they will continue to compost in future. Lead farmers played a major role in helping others. Most lead farmers collaborated with an extension service agent primarily for more education and technical support. Lead farmers met with a lot of other farmers. Generally, people feel that composting is not incredibly difficult. Access to calcium inputs and manure are major challenges to composting. Most farmers think others will try composting when results speak for themselves and as farmers harvest bountiful harvest from composted farms.

The study demonstrated that about although 50% of farmers had heard of compost, many people had not tried it because they didn't know how, however, village leaders said farmers were concerned about workload. Most farmers who tried compost said leaves were greener and yields were increased from composting. People either trusted JGI a lot or they did not know if they can be trusted (n=218). However, they placed a high level of trust in extension service agents (n=284). Nevertheless, village leaders felt JGI was a trusted change agent. Lead farmers agreed that composting on one's farm leads to more bountiful crops and improved nutrition for one's family (n=289). Fertile soil was essential for bountiful crops (n=298). Composting can improve one's soil so that one doesn't have to create new farms somewhere else (n=218). Lead farmers were very happy with their experience working with JGI on composting program and they enjoyed being a lead farmer because they became close with other farmers.

BCC Midterm Evaluation Survey (July 2022)

The midterm evaluation survey had the following findings about the composting behavior change campaign under the LCWT: 96% of all farmers believed that compost makes soil more fertile. Trained and untrained farmers used compost because it improves soil fertility (37%), it improves productivity (36%), and it is cheap (16%). 92% of the treatment group farmers believe that their harvest has improved with compost and 61% of the treatment group say that they have enough compost to meet their needs. Farmers report improved harvest with compost rather than in previous years. In 2021, trained farmers harvested 4% more maize than untrained farmers. In 2021 trained farmers harvested more cassava than untrained farmers. In 2022, trained farmers harvested 31% more cassava than untrained farmers. Income from sale of vegetables had increased due to higher productivity where applied compost does well to tomatoes, watermelon, amaranthus, onions and spinach. Farmers believed that benefits of composting outweighed the time and efforts it requires. 93% of all farmers believed that composting worth time and effort put into it.

Farmers are willing to spend time and effort to compost to ensure long term soil fertility. 70.23% used compost for three (3) or more harvests. 92% of the farmers believe composting will become a common agricultural practice in their communities. 49% of all farmers believed that friends and families who do not currently compost will try composting. The number one source of trusted information for treatment group farmers was JGI (27%). The number one sources of trusted information for control group farmers was friends (21%). In 2021: 84% of trained and untrained farmers used nothing or chemical fertilizers to fertilize their land. In 2022: 83% of trained and untrained farmers used compost while 88% of control group used chemical fertilizers.

The greatest motivator for farmers to start composting was to have a proof of increased soil fertility (39%). 54% of these farmers also believe that this proof is necessary for motivating others to compost. Trained and untrained farmers (60%) said that lead farmers were the greatest influence on them for trying compost the first time. Trained farmers said that JGI (55%) was the source of influence on co posting for the first time, 43% said lead farmers and untrained farmers said lead farmers (80%) were the sources of influence.

In 2021: 39% of the trained and untrained farmers knew of the other farming in the nearby forests. In 2022: 33% of the farmers knew others who have stopped farming in the nearby forest after composting. Out of the farmers surveyed that were trained only three (3) were not composting due to the following reasons no time and money, don't know how, no time and no money. Women were more likely to support composting than men and were also more likely to have children or JGI-trained farmers help them compost. Spontaneous were influenced by lead farmers to compost. 89% of the trained farmers were aware of the compost demonstration plots and 90% of these farmers also found the plots to be useful.

Findings from focus group discussions/ and interviews showed that the campaign activities such as theatre performances that discussed the benefits of environmental conservation, not destroying natural habitats and farming near homes people related with. Football matches were highly popular and well attended. Music and dancing, poems and storytelling on gender roles were also mentioned as favourites. Trained and untrained farmers also reported seeing compost piles at schools, residential areas, open spaces, mosques, churches, and other areas for water collection. 77% of farmers said that the incentives that JGI provided to compost farmers were sufficient. For participants that did not believe JGI's incentives were sufficient (n=18), their reasons were: more tools were needed (5), more money (4), better education/ training (3), need access to water, manure and support to keep dairy cow (1) would prefer public meetings about composting. In 2021: 25% of trained and untrained farmers trusted Agricultural Extension Service Agents more than JGI staff for information on farming (19%), in 2022: Agriculture Extension Service Agents were trusted significantly less (15%) than JGI staff (27%).

Linking the findings with the TACARE Model of Community-Led Conservation

Listen	Understand	Engage	Facilitate	Step Back		
Partnerships	Training	Tools support	Compost Radio series	Partial/ Complete project withdrawal from compost intervention in the village		
Lead farmers	Free compost support	Calendars & Compost tutorials	Lead farmers			
Compost Radio series	Demo plots establishment	Compost Radio series	Billboards &Branding			
Theatre driven community events	Soil Testing	Ongoing support from lead farmers, Extension Service Agents & JGI	Football & Netball games		Increased reports on wildlife (particularly chimpanzees) presence in village land forest reserves	
Billboard & Branding						
Creating Awareness	**Fostering Intention**	**Action & Action Maintenance of Action**	**Social Diffusion**		**Threat Reduction**	**Conserva-tion Goal**

The presented data was analysed as whether they conformed to *TACARE* (Pintea, L, et al.2023) process of Engaging, Listening, Understanding, Facilitating and Stepping Back to internalize the Composting Behaviour Change Campaign intentions to change community's behaviour, perceptions, and attitudes towards shifting cultivation to save the chimpanzees as presented in the findings.

Engagement: From the Socioeconomic baseline, it is event that the Landscape Conservation in Western Tanzania project engaged the communities to know the threats that were posing challenges in the chimpanzees' conservation in Western Tanzania. The campaign design team considered at length the drivers and impact of shifting agriculture and used them in choosing the behaviour, identifying key audiences and villages to pilot and scale up the composting campaign. This piece of research was an important dialogue and bridge between the communities in the landscape and the project engagement in designing a robust campaign that helped shifting peoples thinking from shifting agriculture to sedentary farming near people's homes reviving hope in farming in the fields that once had lost their fertility due to overcultivation. Engagement of communities through research, community meetings, and individual consultations with the project enabled farmers to rejuvenate the zeal for agriculture in support of organic farming and land use planning that was building food security for families and increasing incomes at family levels. As noted in some stories of impact from Idda Joel Sunuka-Uvinza District, Kigoma region) and Mbuke Luvinza (Vikonge-Tanganyika District, Katavi region) improvement of living standards occurred due to their engagement in the USAID Landscape Conservation in Western Tanzania's compost program. Constant transparent communication with farmers helped the project to know kind of challenges communities were facing to determine how they could be supported as it was the case of rescue of the Elephant from Lake Tanganyika as well as the protection of some wildlife visiting villages in the campaign area (refer to appendix).

Listening: The research findings, community engagement and day to day monitoring of the composting campaign progress were used a window to listen to communities' challenges, their aspirations and hopes as well as to the suggested solutions to create an informed intervention that comprised community's solutions combined with science to produce and implement a campaign that was supporting families to overcome some livelihoods challenges to limit forest encroachment. It was not only reading the findings with the ear to listening to communities' challenges and suggested solutions but also to see how feasible the solutions suggested by the project do not complicate the challenge the community is trying to overcome. For instance, one of the challenges compost farmers mentioned to hamper the campaign in all the studies was the availability of animal manure. As the project, assisted by the Tanzania Agriculture Research Institute (TARI)-Tumbi Tabora came up with a solution of using locally made compost manure as an alternative to animal manure to produce more compost fertilizer. Through listening to the research findings, the project was able to facilitate the lead farmers with some branded uniforms to be recognized as a special group of people in the campaign activities as well were offered some special trainings such as communication and para-extension service agents training as recognition in of support farmers in their respective groups who were facing agriculture challenges This made the lead farmers the immediate points of contact for compost farmers, government agriculture extension service agents and the project especially where there were a few or less committed extension service agents to support the composting work in their villages and wards.

Understanding: It takes to wear one's pair of shoes to understand the kind of pain one is going through. To understand community challenges and suggested solutions, the project relied on its BCC surveys, deeper discussions with insights of long serving staff of the Jane Goodall Institute such as Aristides Kashula, Emmanuel Mtiti and from science perspective Professor Lilian Pintea before the Behavior Change Campaign was implemented. Due to no travel restrictions due to COVID 19 Pandemic in 2020, weekly meetings with the BCC Planning Team comprising JGI Tanzania and JGI USA, BCC consultants such as Impact by Design and Nature Agro were conducted to understand the campaign development and emerging issues around it so that to plan solutions ahead of time. Keen interest of the Campaign team was placed for instance on why Kajeje poorly performed during the pilot and why Sunuka performed poorly during the full launch of the composting behaviour change campaign compared to other full BCC villages. Although the extension service agents seemed highly motivated to engage Kajeje farmers in the composting program at the beginning, but the energy went away as the project was not providing incentive compared to other organizations working in the village. Lack of support from the extension service agent resulted into demotivation of farmers and thus leading farmers to create a very few compost piles during the pilot phase. However, selection of farmers according to family lines and low interest of the extension service agent despite the support from the project made the village perform poorly in the full phase of behavior change campaign. Comparatively, excellent village leadership, committed lead compost farmers and extension service agents at Vikonge and Isubangala made both villages shine during the campaign even though the villages were not part of full BCC villages. It took time to navigate the factors behind the performance of farmers in a village so that the project could address the challenges to rejuvenate compost farmers' energy to participate in the campaign.

Facilitating: Survey and observation insights provided some ideas on how to facilitate communities to achieve the goals of composting program such as training farmers on soil, soil structure and soil fertility, importance of riverine forests and compost production and application. Provision of commercial compost to the compost farmers to know how the compost looks like and see how it performs in crops before engaging in mass production, supporting farmers with compost tutorial and farming calendar and other branded items such as wheelbarrows, buckets, t-shirts, kangas and branded gumboots to reinforce compost messaging that was also communicated via a composting radio program and installed billboards in the villages were different facilitative models to farmer. The project provided compost training on high value crops as a recommendation generated from the high value crops assessment to bridge the gap of continued farming throughout the year to support farmers with some activities that will make them disengage with harmful activities that would impact riverine forests. .

Stepping back: At times the project had to step back to stop engaging some villages and individual farmers in the campaign to give them a room to reflect on why they feel not to be part of the campaign. This happened to the pilot village Kajeje after the lowest performance in the compost making and application during the pilot phase. The village was left to meditate their need to continue engaging in the campaign. Selection of compost ambassadors from the village namely, Pastor Onesmo James and Raphael Mbiliko to rejuvenate and scaling up the campaign during the full BCC produced a learning curve for the entire village to resume its full engagement in the campaign and garner project's support in the campaign as a result. This move saw Kajeje ranking the first among the full and post pilot villages in the landscape in compost production and application. The compost ambassadors supported by the village government especially the village executive officer restructured the compost farmers groups by dropping the low performing ones and upgrading the spontaneous farmers who appeared to be responsible to lead farmers and trained farmers groups. More support extended to other compost farmers in the village motivated farmers and village leadership to return their trust to JGI. The BCC project management team decided that Kajaje should be part of the full BCC villages due to their decisive commitment and renewed vigour in compost making and application. The project continued to investment to committed compost farmers in Sunuka village despite the way they were selected. Idda influencing his desperate husband, changed the family dynamics and increased bond between the couple, and the family love flourished further shared to the children after seeing great strides of positive changes at the family level, such as a new house built as a result of compost engagement in a few years of in the compost program being one of them. Idda's brought about a competitive spirit among her neighbours who took composting program for granted. Sunuka today, is one of the villages in the landscape which has well managed its wildlife starting with the visiting and rescued elephant from Lake Tanganyika, buffaloes in village land forest reserve, and some visiting chimpanzees in the village. Sunuka, worked closely with other campaign villages such as Kirando and Msihezi in taking action towards the protection of wildlife in their villages, something which is attributed to increased positive behaviors, perception, attitudes and passion for villages' natural resources created by the composting campaign. In the past such wildlife in the villages, like Sunuka, Kirando, Msihezi and many others would be an easy target for poachers for some quick money.

CONCLUSION AND RECOMMENDATION

Blending of TACARE Model of Community Led conservation in the composting behaviour change campaign was made it easy for communities in both the post pilot and full BCC villages taking the USAID Landscape Conservation in Western Tanzania Project in their heart for the protection of the chimpanzees and other wildlife in both the village land forest reserves and local Authority Forest reserves in Kigoma and Katavi regions. The TACARE model helped communities in BCC villages to have an increased ownership of the wildlife to the extent of seeking collaboration with the project, Uvinza District and Tanganyika Councils and other wildlife stakeholders (TAWA, TAWIRI and TANAPA) at the national level. Data informed workplans and data driven decision-making process ensured that communities were fully engaged, listened to, well understood, facilitated, and sometimes, the project would step back to give a community an opportunity to reflect on its decisions and situations at hand for the better engagement with the project. Various surveys such as the socioeconomic baseline survey, the post pilot survey, Midterm BCC Evaluation, and data collected through community observations and conversations during the implementation of the campaign converge towards attributing the outcomes of the composting behaviour change campaign to the TACARE model of community-led conservation. Chimpanzees' conservation in the BCC villages as it is in the entire landscape needed an alternative solution for replenishing fertility in the soil for sustainable agriculture. This challenge needed a comprehensive approach to convince communities to shift perceptions, attitudes, and behaviour towards using composting as an alternative to soil fertility management to increase food security and family incomes among farming communities in the BCC villages. The campaign was underlined by a slogan: *Tunza Udongo, Tunza Familia, Tunza Mazingira," literally translated as "Care for the Soil, Care for the Family, Care for the Environment."*

From the findings, it is evident that there are some positive impacts of the composting campaign on shifting agriculture in the BCC villages in the landscape. The Midterm Evaluation has demonstrated that 33% of farmers know other farmers who have stopped farming in the nearby forests after composting, thus reducing the impact of agriculture on the riverine forests which are key for chimpanzees and habitat conservation. It was also evident from the documented stories of impact (refer pg. 16) that there is improvement of food security, wildlife sittings and reporting resulting from the composting campaign. However, these findings need to be verified further using satellite spatial analysis to determine the amount of ecological improvement in the BCC villages land forest reserves as a result of the composting intervention. The study has also demonstrated that the Composting Behaviour change Campaign well blended the elements of TACARE model of community-led conservation to achieve its results thus confirming Martinez et al. (2021) recommendation that emphasized the importance of providing farmers with training and support in transitioning from shifting agriculture, offering alternative livelihoods opportunities such as agroforestry or sustainable farming practices.

Future efforts should consider focusing on tailored campaign strategies that engage local communities, provide necessary resources and offer alternative livelihood opportunities to achieve long term behaviour change to enhance chimpanzee conservation outcomes in Western Tanzania. This calls for the adoption of the TACARE model of community led conservation in behaviour change campaign designs for conservation initiatives.

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APPENDIX: STORIES OF IMPACT FROM BCC VILLAGES

Cases of Successful Compost Farmers and villages
(From compost farmer's field monitoring visits and story of impacts recording)

From 'Compost Madness' to an instructing, caring and loving wife
Compost bonds couple's love and nurtures children's happiness

A Power Couple Narrative by Idda Joel & Michael Daniel Tongo

The visiting group and the host farmers at Isubangala and Vikonge villages got an opportunity to listen to an account of Mrs Idda Joel and Mr. Michael Daniel Tongo, a composting couple from one of the BCC villages, Sunuka, located in Uvinza District, Kigoma region who decisively decided to venture into composting to sustain their family. 'Although I was member of the Jane Goodall's Roots & Shoots program while at Sunuka Primary School, I was not easily convinced to become a compost farmer by LCWT like wife," said Michael Daniel Tongo, smiling, while standing closely to her well-dressed African attire beautiful wife, Idda Joel. "A shock came to me one day seeing my wife gathering green and brown grasses, mixing them with soil and manure, charcoal dust and pounded bones powder. I thought she was developing some mental illness, as I thought she didn't know what she was doing. I held my patience to learn more what she was doing. One day, I saw her planting some beans with JGI donated compost in two small plots behind our mud bricks- grass thatched house, an area which was a bit rocky and was never tilled since my childhood. The bean crops grew up very well in the composted plot of which she planted a ¼ of a kilogram of beans which was also divided to plant the non-composted plot. She harvested three (3) kilograms of beans in the composted demo plot and ½ a kilogram of beans in the non-composted plot. I told myself this could be the best manure ever which can change our lives altogether." Said Michael Daniel Tongo, passing the microphone to her wife, Idda Joel.

"We used to farm a bit distant from our home. It is hard to estimate the distance from home to the farms in the forest, but it took us 5-6 hours to walk there. You can calculate how much distance this might be if one is walking." Smiling Idda Joel, takes up the narrative from his husband, Michael Daniel Tongo. "The circumstances in the forest farms were not safe to us and to our crops. We engaged so much in cutting down tree to prepare our farms, leaving the land bare. In some cases, our fellow farmers encountered dangerous animals and snakes in the wild during the process. Most of the time wild animals could feed on our crops. Thieves stole a big portion of harvest from our farms before we harvest. This made our progress slow down so much year by year. It became a huge burden to our family. It was an experience of so much sweat with very little harvest to feed our family. When the Jane Goodall Institute came to our village with the composting program, I was selected to become one among compost lead farmers. The project donated some compost to pilot a small demo plot to see the performance of the manure while we were building compost piles for our own compost. I convinced my husband to support me in compost making and application to grow our crops near our home, but he was a bit hesitant. He didn't buy the idea as didn't know what the program was all about. After seeing the growth of beans in a rocky demo plot, he was convinced to be part of the compost program. We began by growing Bambara nuts in a ¾ of an acre where we harvested 30 tins (a tin is equivalent to a 20 kgs bucket) which we sold at Tshs10,000 each and got Tshs 300,000 which was spent on buying four pigs," Smilingly, she said.

"We knew that piggery project would also support us with animal manure for our composting work, we had been struggling to access animal manure before we bought pigs. During the paddy farming season, we piloted compost in a paddy farm of ¾ of an acre size where we harvested 176 tins of husked paddy. We set aside six (6) tins of husked rice for our family's consumption and sold 170 tins @ Ths20,000 each and accrued Tshs 3,400,000 which was spent to build our new mud bricks house with corrugated iron sheets roofing. We also engaged in bean farming in ½ an acre farm where we harvested 12tins of beans. We kept two (2) tins for the family's consumption, and sold 10 tins each @ Tsh50,000. We accrued Tshs 500,000, which was used to buy a sofa set for our family," recounted Idda Joel. "Our family has three children (11 years old girl, 7years old boy and 3years old girl), they all became very happy to see a set of sofa in our new house. I always tell them, '"The progress you see in our family is the outcome of compost making and application,"' she said. "Once they hear me telling them this testimony, they tell me, '"Mom let us make many more compost piles."' This year, the family has grown 1½ acres of paddy with compost which we expect to harvest between 250-300 tins of husked rice," Idda Joel ended the narrative.

Key lessons were summarised from the power couple story of Idda Joel and Michael Daniel Tongo: Idda becoming so determined to learn from the project due to the challenges she was facing in farming in a distant forest; Michael's unusual tolerance of his wife's 'madness' and readiness to listen and learn from her and join her in the compost program was a pillar to the family's success; The couple building and fulfilling a common family dream and vision together, beaconed on composting technology; Idda's daring attitude in piloting compost in unimaginable and difficult piece of land; Idda's bravery of compost piles making without thinking what his husband and other people say; discouraged from distant farming due to loss of crops, insecurity and wasted time to and from the farms which placed the parents and young children in a dangerous situation. The key lessons from the couple to the host and visiting farmers and leaders at Isubangala was the need to produce compost and use it to grow crops to feed their families. The couple's message was "Let everyone join the Jane Goodall's Compost bandwagon to produce compost and use it to retreat from shifting cultivation to save wildlife and forests." Michael testified before his compost farmers colleagues and government leaders that his love for his wife has grown so much more than ever before after their engagement in the compost program. His wife respects him so much and the family bond has become the strongest due to the increased collaboration between the couple in compost farming and improved food security in the family. Today people tell Idda and I, "You look like a brother and a sister." Michael added.

The Fall and Rise of Kajeje

(A Story of Stepping Back and re-listening and understanding, re-engagement and re-facilitation)

A narrative by Pastor Onesmo James and Raphael Mbiliko

As one of three compost pilot villages in 2020, Kajeje was so promising to become a leading village in the compost program. Farmers were well organized under another agriculture program Enabel who was promoting beans farming. The village appeared to have a strong extension service agent who frequently visited and advised them what to do. The extension service agent was being supported by Enabel with a motorbike and a smartphone, monthly mobile top-ups and fuel. This was the impression of and data from Kajeje, the BCC FGD team accumulated during the qualitative data collection to determine why farmers in the landscape practice shifting cultivation in the riverine areas. Due to this impression the village was selected as a compost pilot in Uvinza DC together with Isubangala and Vikonge both in Tanganyika DC to pioneer BCC compost program, before the project launched a full-Scale BCC in a selected number of villages in the landscape. The following is a narrative from Pastor Onesmo James and Raphael Mbiliko on *The fall and rise of Kajeje.*

"Mbiliko and I, were not selected as lead farmers when the compost program came to our village. I belonged to Ms. Riziki Zuberi and my colleague Raphael Mbiliko belonged to Ayubu Lemezo's group. Our village did not perform well during the pilot phase, as only 28 out 55 farmers created compost piles and out of 28 piles, 11 piles were turned up. We created compost pilot plots which were not well managed as most of them were attacked by termites and diseases. The commercial compost arrived a little late, off the planting season. During the post pilot compost program handover workshop in Katavi, in which village leaders, extension service agents, district and regional agriculture experts took part, it was very sad to us to learn that our lead farmers, extension service agent, district and regional officials to learn that our village had become the last in the pilot phase while Isubangala led all the three villages by creating 66 compost piles and well managed her 55 compost pilot plots followed by Vikonge with 33 compost piles with 55 pilot plots. We didn't participate in this meeting but the directive from our lead farmers, extension service agent and village leadership was to go for an ambitious target of 1250 piles by the end of 2021. This seemed impossible given the experience we went through during the pilot phase. While Kajeje had set this goal, Isubangala whis was the giant of all the three villages, set a target of creating 500 piles followed by Vikonge 275 piles. As one of successful farmers in the village, I was selected by the project to represent Kajeje in the Full BCC launch as a compost ambassador," siaid Onesmo Jemas, "Joining a team of other ambassadors from Vikonge village Neema Mbuya and Mbuke Luvinza Nh'ala and Isubangala's Khalid Songambele, Lucy Phidos, Sophia Morris, Felister Joachim and Ramadhan Shiganza to train new farmers in compost making and application in eight (8) BCC villages in Uvinza District. Government leaders and project staff asked me if I knew why the project had chosen me and left all the lead farmers in your village to become the compost ambassador. It is because "we have trust in you and we believe you can make Kajeje stand up." During all the time of the farmer training in the BCC villages and full launch of BCC, I felt bad when project staff, district and regional leaders referred to Kajeje as the worst performing village during the pilot phase. My word to them was "Kajeje will do well, give us time." When the project launched the full BCC with theatre driven community events, the situation on my side was worse, especially when other compost ambassadors provided success stories from their villages and their own personal accounts of the composting program. I had only my story which wasn't enough and powerful to project my emerging vision of a new Kajeje compared to other compost ambassadors. Mine was a popular rhetoric of Kajeje's failure.

Whenever, I went home, I shared with my lead farmers on what was going on in other composting villages in the full BCC villages and Post Pilot villages. The project was distributing branded items and farming tools to lead and follower farmers in the full BCC villages but Kajeje wasn't mentioned in the items which were being distributed. It is like the project district, and regional leadership were giving up on Kajeje. I had to consult with my village government with lead farmers. We agreed that every Saturday would be a day I receive data on compost making from all lead farmers in the village. Kajeje started rising again. I strategized with lead farmers on how to make Kajeje rise but some didn't buy my idea. I asked for consent from my village government to remove all compost lead farmers who didn't match with our pace. I replaced Issa Alfan with Shaban Maganga and put Mbiliko to replace Ayoub Lemezo. This change started seeing compost piles being created. We recruited new compost famers and trained them how to make compost. The competitive attitude of producing and applying compost was intensified by the WhatsApp created by the project. Every time there were weekly updates from the entire landscape on the progress on composting. This made the project staff change its mind by including Kajeje as one of the BCC villages. Kajeje became a leading village in making and using compost. By April 2022, the village had created 904 piles also producing the leading compost farmer in the landscape with many piles (104), followed by Isubangala which had more than 700piles and the leading female compost producer in the landscape, Sophia Morris with 101 piles." The village is now leading among compost villages in the landscape in compost horticultural farming after being trained by the project on high value crops in collaboration with Balton Tanzania limited. The secret behind Kajeje success was contributed to a number of factors including consultative meetings with village government council, changing compost leadership systems, discovering strategies of the competitor; the best use of social media; compost farmers participation in strategizing on compost making; designing alternative approaches for accessing composting had to get raw materials i.e. reaching out to slaughter houses for calcium sources and requesting children to collect snail shells; understanding and internalizing the project's agenda. To date Kajeje has created a cumulative total amounting to 1615 piles since the inception of the program in 2020 becoming the second after Isubangala which has a cumulative total pile amounting to 1938 piles and Vikonge 1469 piles. The leading women in compost making is Lucy Phidos (Isubangala) with a cumulative total compost piles 203, followed by Sophia Morris (Isubangala) with 185 compost piles, followed by Raphael Mbiliko (Kajeje) with 180 piles and Onesmo James (Kajeje) 103 piles. The village had done very well in netball competition becoming the winner of compost championship," Onesmo James concluded.

BCC Communities Increase awareness and heighten Protection and Conservation Actions towards wildlife

The story of BCC Wildlife Conservation Champions

Honda Issaya-FM/VGS (Sunuka), Seleshi Ezra-Fisherman (Sunuka), Ahamad Ramadhan-Compost Lead Farmer (Kirando), Abdu Kimori-Compost farmer (Kirando) and Ms. Kedelia Ezekiel Compost Farmer (Msihezi)

The major goal of the Jane Goodall Institute and the Landscape Conservation in Western Tanzania is to conserve chimpanzees and their habitats. The goal of BCC is to promote the use of compost to improve soil fertility hence increase crop production to improve food security and family health so that to reduce shifting cultivation to improve the health of chimpanzee's habitats (riverine areas). Since the engagement of communities in the compost program through the behaviour change campaign in 2021, communities in the BCC villages in the landscape have reported increased sightings of wildlife in their villages after a long time, something which some members of the communities interpreted as reduced interference of animal habitats by human beings through shifting cultivation.

The period between September 2022-February 2023, four BCC villages reported sighting/ being visited by wildlife in their villages which they reported to the project for assistance of redirecting the animals back to the natural habitats. The wildlife sighted in the village settlements include an elephant which was roaming at Msihezi, Kirando and Sunuka villages, two buffalos which were roaming at the outskirts of Sunuka village and a group of four chimpanzees including a baby visiting Msihezi village, Muungano-Zingatia hamlet in Uvinza District.

The most interesting part of the stories from the communities was the courage of some members of the communities to protect the wildlife in their villages by communicating with the relevant conservation partners such as JGI-LCWT project composting and monitoring section, village governments, community police and other security organs in the area. Due to too much pressure from people who wanted to see the elephant at Sunuka, the elephant drowned in the lake for 12 hours until compost farmers and other conservation champions rescued her from the lake. This story was shared to the communities at Isubangala and Vikonge because there some reports of a caucus of a chimpanzee in Mishamo settlement last year and they were reports of sighting elephants in villages in the Mishamo settlement. The project believes that if likely incidences occur in the villages around Mishamo settlement and Vikonge again, steps taken by wildlife conservation champions in Uvinza DC would be taken by communities in Mishamo Settlement and Vikonge villages to save the wildlife.

The following is a story of how compost farmers at Kirando and Sunuka rescued a capsizing elephant from Lake Tanganyika….

"When I heard about the elephant in our village, I had to reach out our compost project leader, Robert Mkosamali for his assistance," said Ahmad Ramadhan a compost farmer from Kirando. "I also communicated with the village leadership to request for assistance from community police to deter people from going close to the elephant as this would be dangerous to do, as I was advised by Robert Mkosamali. The elephant had attacked someone on a motorbike. A few days later it was reported to have been seen at Sunuka village and many people from several villages had flocked to see her. While at Sunuka, the elephant was reported to have demolished a house and consumed watermelons from a garden in the village," said Ahmad Ramadhan. "The pressure from the multitude of people pushed the elephant into lake Tanganyika thinking it was a small river to cross easily. It was said that elephants have poor sight. Wildlife experts say it can see not more than 10 metres, narrated Honda Issaya, the village game scout from Sunuka. I intensified communication with USAID Landscape Conservation in Western Tanzania project staff-GIS officer, Paul Mjema by sending photos to Decision Support System (DSS) created by the project to seek support on how to rescue the elephant from the Lake. I was told that the JGI team was in a meeting discussing about the matter and would revert back to me after the meeting. The team on the ground reached out to the village government for some fuel which allowed the village rescue team to proceed with the mission while waiting for any support from the project and district authorities. The communication on the DSS had already reached major decision makers and were coordinating how to rescue the elephant and return it back to the forest.'' Honda retorted. "The intention of many people who flocked to see the elephant was to kill the elephant so that the meat could be distributed to the community," added Seleshi Ezra, a brave young man who tied a rope to the elephant's rear leg for her rescue from drowning. "But animals have their position in our lives just like we human beings are to the animals. They can see things which human beings can't see, so we need to respect and protect them," Seleshi added.

"I was not feeling well when the news about the elephant roaming in our village reached my ears. I was being disturbed by my eyes," said Seleshi Ezra, one of fishermen in Sunuka village. When I felt better, I was told that fishermen had spotted the elephant in the deep waters of Lake Tanganyika along Lubengera-Msihezi area. I knew this was the only opportunity for me to see the elephant which I had not seen when I was sick. I coordinated a rescue team with Rama Uledi, Honda Isaya, Tumbaa, Agogo and Rama Issa Mkanda, and Yahya Kassembe (Forest Monitor/Village Game Scout- Kirando village). We organized a small boat (15 horsepower) with five (5) litres of petrol and sailed to where the elephant had been sighted by the fishermen. While in deep waters, we saw the elephant was tired and it appeared the stomach was full of water. When it saw the boats near it, it placed its truck on one of the two boats, which were tired together, and it started rotating the boats. This posed a bit of risk to us. I told the rescue team my plan is to dive into the water and tie one of its legs so that we can pull it to the shore. Some opposed to that idea, and I suggested another idea tying it using a slip knot rope while in the boat. This worked perfectly. After tying it to our boats, we started sailing back to the village pulling the elephant from deep to ashore following the Kirando direction which appeared to be the closest distance. As the elephant was too heavy, we reached a point the boat engine got a break-down. We had to request for assistance from Abdu Kimori's boat from Kirando, which had some fuel to come to our assistance. Abdu tied our boats and started pulling us with the elephant ashore. We had to draw a landing plan once the elephant reached the shallow waters as it might turn aggressive. With the assistance of Honda Issaya, Sunuka village Forest monitor/Village Game Scout who was constantly communicating with the Jane Goodall Institute team and District authorities on how to handle the elephant. When we reached the shallow waters, the elephant became too heavy, and we decided to cut off the rope connecting the our boats and the elephant to set the elephant free near the Luguvu river's mouth which spites its water into Lake Tanganyika as per Honda's advice. Honda's concern was that the mouth of Luguvu river was full of hungry crocodiles which might kill the elephant. Fortunately, the elephant was well received by the community of crocs and nothing happened to it. The team remained vigilant of the elephant when the rescue team from JGI and Uvinza district was making its way to the scene." Seleshi Ezra said. "JGI team arrived at Kirando with Uvinza's game officer and they were taken to the scene where the elephant was landed," Ahamad Ramadhan Added.

"The elephant remained in the village for some days being protected by the community led by myself and the district game officer before the team from Tanzania National Parks (TANAPA) and Tanzania Wildlife Authority (TAWA) arrived at the village for purpose of removing the rope from the elephant and driving it back to the wild," added Honda Issaya. "The elephant was tranquilized; the rope was removed and a boil near one of its ears treated. The team tried to push it back to the wild, but the elephant couldn't go. It was very well acclimatized to the environment and the people. The experts used some explosives and pepper to scare it and make her go back to the forest but she didn't respond to the sounds of the explosives neither the itching pepper. She stayed in the village for five months being guarded by the community and TANAPA's paramilitary officers until parties reached an alternative solution to relocate her to a nearby game reserve. While monitoring the elephant in the village, I received a report that two buffalos had visited our village. I went to where they were and took photos of them for the purpose of sharing them with the project," Honda concluded the story.

A Compost Lead Farmer Protects a Baby Chimpanzee

An account of Ms. Kedelia Ezekiel Daniel

Her name is Ms. Kedelia Ezekiel (44 years old), a widowed with 11 children (the first child born is 23 years old and the last is three (3) years old), a resident of Msihezi village, Sunuka Ward in Uvinza District, Kigoma region. On 30th September 2022, I (Robert Mkosamali) received a call from her telling me that there is a baby chimp which has been left in a tree in the village by its family of three adult chimps and she didn't know what she could do to rescue the baby chimp. As I was already in BCC villages, coordinating a compost netball competition, I had to respond quickly to the request of Kedelia Ezekiel. It was already late (19:00hrs). I requested my driver to drive me to the village which was about 10 Kilometres from the base. Once I was there, I gave Kedelia a call, letting her know that I was already in the village ready to visit the baby chimp in the tree. By that time, it was approaching 20:00 and there was a bit of moonlight covered by dark clouds.

Ms. Kedelia narrates…

"Before joining the compost program of the Jane Goodall Institute, I was a farmer who used to make charcoal to meet needs of my family. I used to harvest trees from my colleagues' farms in the village without their permission, make charcoal and sell it. Something which was not good. I joined compost making program and was trained on good agricultural practices to increase crop production. Currently, I'm a compost lead farmer in our village. It was on 28 September 2022, when I was told by my one of villages residents, '"Kedelia, you guys who support the environmental conservation in our village, come and see your chimpanzees, I think now the time has come that we shall be moved away from our village to allow expansion of chimpanzee conservation by the Jane Goodall institute,"' said Kedelia.

"We went to the scene which was behind a Juksuta Mosque to see a baby chimp eating some fresh leaves and fruits in a big tree. My First instinct was to inform my hamlet leader, Bitega Hamis about the situation who reached out to the village Land Use Planning Management Team and the Forest Monitor/ Village Game Scout for Msihezi for more assistance. The hamlet leader told me that that has been their corridor since time in memorial. I reached out to JGI compost program leader-Robert Mkosamali to give him the information about the visiting chimpanzees in our village. Since he was already at Sunuka running the compost netball tournament, he drove to the village that night and I took him to the big tree where the baby chimp was sleeping. He advised that we should not allow people to approach the area as other chimpanzee will find it hard to come for the baby's rescue and the baby will not feel safe to descend from the tree. We had to arrange with my late husband how to guard the baby chimp from interference of people in the village. It appears the group of four chimpanzees came from Kalumpeta village land forest reserve going to Kabogo village land forest reserve. On the way, they left the baby chimp on a tree. We could hear exchange of pant hoots between the adult chimpanzees while at Kalumpeta village forest reserve with the baby chimp at the village tree. After seven days baby chimp at the tree, the adult chimpanzees came back to the tree, picked it up and they all returned to the Kabogo village forest reserve," Ms. Kedelia ended her story.

From an illiterate wife to a Successful Training Compost Ambassador:

Mbuke's engagement in Compost program Changes Family Dynamics

A Power Couple Account.

September 2020, a team from the Jane Goodall Institute-LCWT project visited Vikonge village in Tanganyika DC, Katavi region for purpose of introducing a compost pilot program in the village. Vikonge was among three villages which were selected by the project to pioneer compost in the landscape. The other two villages were Isubangala in Mishamo Settlement in Tanganyika District, Katavi region and Kajeje located in Uvinza DC, Kigoma region. During the meeting, the project requested the village council to appoint 20 committed and dedicated farmers

to be part of the composting program in the village. Among the council's members was Mosses Mashishanga a husband to Mbuke Luvinza N'nala, a young lady who was not exposed to education due to mobility of her agropastoral parents. Mosses Mashishanga decides that one of farmers from his hamlet Kanegele would be her wife, Mbuke Luvinza.

But when the message lands to Mbuke, she resists to be part of the program because she feels unconfident and unwilling to be part of the project because she is illiterate. Mbuke's position develops an argument between the couple. The reasons why Mbuke should be part of the program dominates Mashishanga's mind and makes him infuriated by his wife's resistance. However, Mbuke stands with her position that his husband Mshishanga had some malice behind his appointing her to be part of the program. According to her his husband wanted to expose her to people that she is illiterate so that she can be ridiculed.

Mbuke narrates…

"Naturally I'm a shy person. When my husband told me about joining the compost program, I felt not able to do what the project wanted. I fought with my husband who was still insisting that I should join the program. But I resisted. He said, he would divorce me if I will not be part of the program. I felt not happy with his position. He rang the village chair to convince me to be part of the program. I eventually partially accepted to join the program, but heart wasn't into it. The next day I went for the interviews with the project staff at the village office. I was selected to be the youngest female lead farmer to lead our hamlet in the compost program. A total of five (5) lead farmers had been selected in our village. Out of which two were female farmers Ms. Restituta Kulyehelwa and Myself. My husband and I, used to rely on traditional medicine in the past to increase crop yields in our farms. He could pay up Tshs 500,000/- to a traditional medicine man to help us with medicine to support increase our crop production. When the project came to our village, we were trained on soils and soil nutrients and important minerals for crop production and how we can use compost to restore soil fertility. We were also trained on importance of forests in agriculture. I managed to recruit 10 farmers in my group out of which three (3) were women. With the support of my husband, who was also a follower farmer in my group, we managed to create 11 piles and 11 pilot compost farms in our hamlet, where we planted maize. After the pilot phase I became on top of all famers in compost production and application in our village, beating all male lead farmers. The second was my fellow female lead farmer, Restituta Kulyehelwa from Infisi hamlet," Mbuke Luvinza N'nala said.

"After the pilot phase, the project selected Restituta and I among the lead farmers and Neema Mbuya our Extension service agent from our village to become the compost ambassadors to scale up compost technology in nine villages in Uvinza District. We were joined by Felister Joachim, Lucy Fidos, Sophia Morris, Khalid Songambele and Ramadhan Shiganza (another extension service agent) from Isubangala village from the Mishamo Settlement. We trained 110 farmers at Lyabusende and Kangwena villages. While at Uvinza, I asked my husband what we I should do with the money I receive as allowance from the training. We decided that we build a new house and buy a new TV set and decoder to watch football matches with my family. Our family engages in agroforestry, sunflower, cotton, paddy and cashew farming," said Mbuke Luvinza. "I was selected as a model farmer last year to represent Tanganyika District in the Farmer's Day, Nane nane exhibition in Mbeya because of our improved agricultural practices," added Mosses Mashishanga. "We receive visitors in our family from district and regional offices who come to learn what we do in compost and agroforestry projects. In our new group in our village christened Kilimo Kwanza (literally meaning, Agriculture First), we managed to conduct farmers' Field day with the support from our Extension Service Agent, Neema. We have learned kitchen gardening, which makes it easy for us to get vegetables right from home," added Mbuke. Mosses Mashishanga has taken one step forward to support his wife acquire education. He has allowed her to start learning at the primary level because he believes his wife can achieve a lot if she is exposed to the formal education.

HUMAN-BAT INTERACTION: A POSSIBLE SOURCE FOR THE OUTBREAK OF MARBURG VIRUS DISEASE IN MARCH 2023 IN KAGERA REGION, NORTHWESTERN TANZANIA

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ABSTRACT

Marburg virus disease (MVD) was a central issue in emerging and re-emerging zoonotic viral disease in Tanzania, in 2023. It is the first outbreak of viral hemorrhagic fever in the country and had a case fatality of 66.7%. The disease is caused by the Marburg virus (MARV) belonging to the Filoviridae family of viruses. Ebolavirus and Marburgvirus, which are Filoviruses, pose a significant threat to public health and species conservation by causing hemorrhagic fever outbreaks with high mortality rates. As a zoonotic disease, MVD is transmitted to humans through saliva, feces, and contaminated fruits from mainly bats (primary reservoirs), and African green monkeys and pigs (potential amplifier hosts). In identifying the potential risk factors for MVD outbreak, an ecological study for MARV was conducted to identify the potential bat species that normally serve as reservoirs for MARV and the way they interact with humans in Kagera region in Tanzania. Face-to-face interviews, inspection of the trees, buildings, and other structures like caves, and netting methods were used. In 18 surveyed sites, Egyptian fruit bats, Hairy slit-faced bats, Noack's roundleaf bats, and African sheath-tailed bats were identified. The bats interacted with humans in the living houses, caves, rocky crevices, and abandoned mineshafts whereby guano collection (61.1%), mining (16.7%), and tourism (5.6%) activities were the main interaction causes. The index case of the outbreak was among the guano collectors, two weeks before his sickness, he participated in bat manure collection in the caves occupied by Egyptian fruit bats. This might be the possible transmission pathway of the virus from bats to humans which is followed by human-human transmission. These data indicate the Egyptian fruit bats present in caves located in Kanyangereko can be the source of MARV with potential for spillover into humans through the cave visiting in Kagera, Tanzania.

Keywords: Marburgvirus, One-health approach, *Rousettus aegyptiacus*, Tanzania, Zoonoses

INTRODUCTION

Marburg virus disease (MVD) is a severe andoften fatal illness in humans caused by the Marburg virus (MARV) (WHO, 2021). The virus causes severe viral hemorrhagic fever in humans. Both the Marburg and Ebola filoviruses cause a severe, fatal, disease in humans and nonhuman primates but have only subclinical effects in bats, including Egyptian rosettes, which are a natural reservoir of the Marburg virus, and when infected, shed virus in the highest amounts in oral secretions and urine (WHO, 2021; Jayaprakash *et al,* 2023; UK GOV, 2023). Both monkeys and pigs are susceptible to Marburg virus infection and shed the virus, however, the monkeys are not considered reservoir hosts as they usually die rapidly once infected (UK GOV, 2023). The Marburg virus is transmitted to people from fruit bats and spreads among humans through human-to-human transmission with no apparent disease in the fruit bats (WHO, 2021). However, Olival and Hayman (2014) found that, fruit bats have been identified as the primary natural reservoir for the Marburg virus with reservoir dynamics of inter and intra-species transmission of virus within bats, and that suspected from bats to non-human primates. The spillover dynamics involve the direct transmission of the Marburg virus from bats to humans, bats to non-human primates, and non-human primates to humans (Olival and Hayman, 2014).

Marburg virus was first recognized in 1967 when simultaneous outbreaks of hemorrhagic fever occurred in laboratories in Marburg and Frankfurt, Germany and in Belgrade, Yugoslavia (now Serbia) (CDC, 2023). The outbreak was associated with laboratory work using African green monkeys (*Cercopithecus aethiops*) imported from Uganda (WHO, 2021). Since the first outbreak, their origins, natural history, and ecology remained elusive until recent studies linked them through molecular, serological, and virological studies to bats (Olival and Hayman, 2014). According to the UK Health Security Agency (2023), within these six decades of the Marburg virus, a total of eighteen outbreaks involving 14 countries have been reported worldwide. The outbreaks include 643 reported cases of which 522 deaths occurred. This makes an average case fatality rate for Marburg virus disease 81.2% for all reported cases from 1967 until June 2023 (UK GOV, 2023).

Following the high mortality rates to host mammals caused by hemorrhagic fever, *Ebolavirus* and *Marburgvirus*, pose significant threats to public health and species conservation. Human entry into bat-infested mines and caves has been associated with the majority of naturally occurring MVD outbreaks, suggesting that bats play a key role in MARV transmission (ECDC, 2023). The bat species that have been confirmed to be the reservoir of Marburg virus are *Epomops franqueti, Hypsignathus monstrosus, Miniopterus inflatus, Rhinolophus eloquens,* and *Rousettus aegyptiacus* (Olival and Hayman, 2014).

Tanzania had a laboratory-confirmed case of MVD reported for the first time on March 21 2023. The Minister responsible for Health in the United Republic of Tanzania declared the Outbreak of MVD in the Bukoba district in the Kagera region on the same date. Nine (9) cases were reported, resulting in six (6) deaths, indicating a case fatality rate (CFR) of 66.7%. Tanzania has diverse bat species from insectivorous to fruit-eating bats, of which some were observed in Bukoba inhabiting both the households and the wild. The presence of some interaction between humans and bats in the area heightened a need for a multi-sectoral and multi-disciplinary team to address the issue. A multi-sectoral survey to explore reservoir bats associated with an outbreak of Marburg Virus Disease in the Kagera region was conducted. The main objective of this study was to identify bat species and their interaction with humans as one of the risk factors for viral spread.

MATERIALS AND METHODS

Study design and area

This was a cross-sectional study conducted in Kagera region located in the northwestern part of Tanzania. The region is bordered by Uganda to the north, Rwanda to the west and Burundi to the southwest. The study was conducted in three districts of the Kagera region namely, Bukoba Municipal Council, Bukoba, Muleba and Kyerwa District Councils. The study districts were selected purposively as were affected by Marburg outbreaks, other districts with no cases were selected because of their closest risks of the contacts. In Bukoba district, Kanyangereko ward which was the epicenter of an outbreak was among the fourteen (14) studied wards.

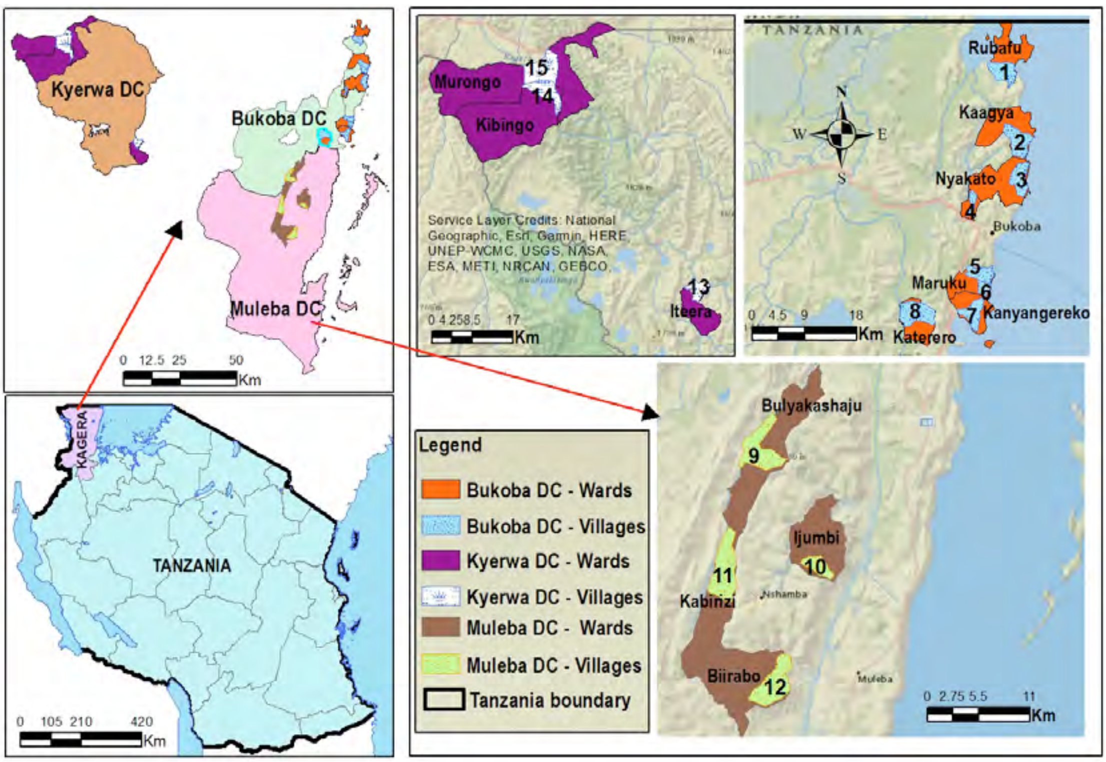

Figure 1: A map of Kagera region in Tanzania showing the districts, wards and villages surveyed during the study. The numbers 1 to 15 representing the villages (1-Katale, 2-Katangalala, 3-Ibosa, 4-Ihyoro, 5-Kyansozi, 6-Maruku, 7-Butahyaibega, 8-Kyema, 9-Nyakahama, 10-Ibare, 11-Kabirizi, 12-Kabare, 13-Muleba, 14-Rugasha, 15-Murongo).

Study population, size and sampling

The survey involved thirty-four (34) people (key informants), 639 bats and the environment around households where Marburg outbreak occurred and those in selected districts with no cases. All available habitations of bats in all selected villages of the selected councils were surveyed. In each identified site/colony of bats, the population and species composition were established.

DATA COLLECTION TECHNIQUE AND TOOLS

Identification of bat species

Despite the fruit bats being the primary natural reservoir for the Marburg virus, other bat species have been associated with spillover dynamics of the MARV. Therefore, the study involved all bats in the area. The pre-information was conveyed to village leaders to list the roosting sites in their villages. However, the survey team did not rely on their information alone, instead, the buildings, trees, caves, rocky cracks or crevices, and abandoned mineshafts were inspected for roosts as guided by Mitchell-Jones (2004). The Geographical Positioning System (GPS) coordinates of surveyed areas were taken for mapping (Not mapped).

Capture of bats

Bat capture and species identification were done using mist nets, binoculars and cameras. The mist nets were used to capture bats in caves and buildings, while leather-gloved hand capture was conducted in some buildings. The photographs were taken in situ at roosting sites to identify individual bat species and species composition. Depending on colony size, between 2 to 70 bats were captured in each roosting site, to make a total of 639 captured bats. The capture was done during the daytime only. A few captured bats were placed in breathable cotton bags, which were moisturized to prevent animal dehydration.

Identification of bats

The captured bats were taken out of breathable cotton bags on sufficient light to be morphologically studied and photos were taken using a Nikon COOLPIX P100 camera (Nikon Thailand). Finally, the bats were released. However, some were euthanized using standard protocols. The capture and species identification were conducted as described by Pourrut *et al.* (2007), and Patterson and Webala (2012). Additionally, the taken photos were compared with other online published photos of the bats observed under the AfriBats project (https://www.inaturalist.org/projects/afribats) to confirm the species.

Interactions between humans, bats and the environment in Kagera regionObservation

Environmental observation by the team was conducted to identify the presence of Marburg risk components such as bats (species identification e.g., *Rousettus aegyptiacus*), caves, non-human primates (monkeys) (Pigott *et al.* 2015), fruits, livestock (pigs), shared water bodies (e.g., rivers). A checklist was used to gather information on the presence of the roosting site, GPS coordinates, activities conducted on the site, activities conducted surrounding the site, and the distance from the roosting site to human settlement. A checklist was prepared and administered in an electronic form (Kobocollect) in Android devices that helped the transfer of data to Microsoft Excel Spreadsheet 2019 version 1808 (Microsoft Office Professional Plus 2019)

Face-to-face interview

Quantitative information was gathered from key informants who were involved in the survey. An interview guide was prepared from the checklist hints and the questions were administered to collect supplementary information on the observations made to determine the possible transmission pathways and presence of interactions with bats. Two to four key informants in each surveyed village/ward responded to the interview either knowingly or unknowingly through asked questions. The main criterion for the key informants' selection was their understanding of bat habitats in the villages/wards and having interacted with these habitats in one way or another. A total of thirty-four (34) key informants were involved in this study sampled from 14 wards.

Biosecurity and biosafety measures during study

All protective measures were observed to protect people, animals and the environment. This includes the use of PPEs, safe handling and disposal of materials. The standard methods and use of Personal Protective Equipment (PPE) followed the safe handling and sampling of mammals that are potentially infected with infectious pathogens (Mills *et al*., 1995).

Ethical considerations

The permissions to conduct the survey were sought from all level of government administration including national and subnational level as part of emergency response. All respondents were informed the aim, benefits and risks of the study and asked for consent verbally. All participants were ensured that the information obtained will be kept strictly confidential and used for decision making purposes only.

RESULTS

Bat species in the Kagera region

A total of eighteen (18) roosting sites were located, of which eleven (11) were caves, three (3) abandoned mineshafts, three (3) buildings and one (1) rocky crevices. The roosts were estimated to be inhabited by more than 50,000 bats. In these roosting sites, four bat species were identified: Egyptian fruit bats or Egyptian rousette (*Rousettus aegyptiacus*), African sheath-tailed bats (*Coleura afra*), Hairy slit-faced bats (*Nycteris hispida*), and Noack's roundleaf bat (*Hipposideros ruber*).

The Egyptian rousettes were identified in nine (50%, n=18) sites, of which six (6) were caves and three (3) abandoned mineshafts in tin mines. African sheath-tailed bats were found in seven (7) sites which include three (3) buildings, three (3) caves and one (1) rocky crevices. The Hairy slit-faced bats and Noack's roundleaf bat species were found in caves of which each species was observed in one site.

Human-Bat interaction

During the study, the interaction activities were between humans-bats, bats and the environment, these were more common within and surrounding the roosting sites. The activities found in roosting sites were manure/guano collection, tin mining, settlement, store/storage, and tourism. While agriculture/crop farming, mining, forestry, livestock keeping, and settlement were continuing in the surroundings.

In eighteen surveyed sites, presence of

guano collection activity was reported by key informants in twelve (61.1%, n=18) sites, tin mining in three (3) sites, storage in two (2) sites, and settlement and tourism were reported in one (1) site each. In activities conducted around the roosting sites, crop farming was the most observed activity (77.8%), followed by settlement (44.4%), tin mining (16.7%), forestry (11.1%), and livestock keeping (5.6%).

During this study, it was found that the index case (Case 1) during Marburg disease outbreak was working closely with his uncle supporting him in collecting bat manure from the caves located in the village. He has been collecting bat manure for a long time and they used the manure for backyard farming and selling to neighbors as his alternative source of income. Between January and March this year (2023), the index case collected the manure more than three times and the last time was two weeks before he started feeling sick when he complained of fever and body weakness. Through selling, the bat manure was supplied in various areas of Bukoba from the villages to the town. In the Kyerwa district, tin mining is the main activity that predisposed the miners to bats in almost all visited sites (100%, n=3).

DISCUSSION

The aim of identifying the bat species and their interaction with humans in Kagera region was the result of the human-bat interactions being associated with many MVD outbreaks in Africa (Towner *et al*., 2009). The bat species identified in the study area had a strong interaction with humans both within and outside their roosting sites. The interactions were found to have strong evidence enough to cause an epidemic in Kagera.

The sporadic outbreaks of Marburg Hemorrhagic fever have been reported in various countries in Africa (Amman *et al*., 2021). The bats of different species were associated with the spread of the Marburg virus to human and non-human primates (Olival and Hayman, 2014). The frugivorous Egyptian rousette bat (ERB) remained to be the leading natural reservoir for the virus. The highest amount of virus is shaded by ERB in urine and saliva (Amman *et al*., 2021). MARV was repeatedly isolated directly from cave-dwelling ERB following a series of MVD outbreaks in Uganda that linked to miners working in Kitaka Mine and tourists visiting Python Cave (Adjemian *et al.*, 2007; Timen *et al*., 2009; Towner *et al*., 2009; Amman *et al*., 2012; Amman *et al*., 2021). ERB and other fruit bats play a great role in the transmission cycle of MARV and Ebola virus as the pieces of evidence proved that, these bats were linked with various outbreaks of hemorrhagic fevers in the Republic of Congo, Gabon, Côte d'Ivoire, Democratic Republic of Congo (DRC), and Ghana (Amman *et al*., 2021).

To be the most observed (50%) and distributed species in all districts during the study, the ERB has the possibility of playing a great role in the outbreak of the MDV in Bukoba district in March 2023. The cave located in Kanyangereko was found to be roosted by a large colony of ERB. This cave is where the index case (Case 1) was reported to visit two weeks before his sickness for manure/guano collection. In2023, the index case reported to have visited the caves about three times for manure collection before falling sick. The use of Personal Protective Equipment (PPE) during manure collection in the caves was not observed. As they get out of the caves, they were found to be wet with bat urine and feces that while sweating make these contaminants reach more parts of the body and hence increase their susceptibility to the virus.

Concerning the normal incubation period of MVD which ranges from 2 to 21 days (WHO, 2021), the two weeks' time falls within the range. The presence of the link between the natural reservoir (ERB), the transmission pathways, and the incubation period (14 days), it is plausible and rational enough to say that, the ERB in the caves were a possible source of MARV transmission to the index case that led to disease outbreak.

African sheath-tailed bat (*Coleura afra*) was among the four (4) bat species identified during the study. These bats were the second (38.9%) in abundance and distribution after ERB in all surveyed areas. The African sheath-tailed bats were found to host an unclassified paramyxovirus named Belinga bat virus (BelPV) following its discovery in bats dwelling in the Belinga caves of Gabon (Maganga *et al.,* 2014). However, the virus proved to be species-specific, with several hemorrhagic lesions at the necropsy of sampled bat of which the viral sequence was obtained (Maganga *et al.,* 2014). Additionally, Crimean Congo Hemorrhagic Fever virus (CCHFV) a member of the genus *Orthonairivirus* has been detected in *C. afra* and other African bats (Kohl *et al*., 2021). This study found no reference that links the *C. afra* outbreak of MVD or the spread of MARV.

Noack's roundleaf bat (*Hipposideros ruber*) is among the bat species of the family Hipposideridae. This bat has been associated with Coronavirus in various conducted studies, in which Duvinacovirus, Hibecovirus, Nobecovirus, and Sarbecovirus were the key detected Coronavirus subgenera (Ruiz-Aravena *et al*., 2022). In Gabon, the Makokou virus (MKV) was detected in *H. ruber* (Witkowski *et al*., 2016; Sudi *et al*., 2018). Also, the bat has been detected with Paramyxovirus similar to what was reported on *C. afra* (Markotter *et al*., 2019). However, the evidence linking the *Hipposideros* spp. to MVD was low as the prevalence of 0.2% (n=609) was established in Uganda (Towner *et al*., 2009).

Less information concerning the diseases and causative agents of the Hairy slit-faced bat (*Nycteris hispida)* is available. However, the *Histoplasma capsulatum* was detected in the intestinal tract of this species of bats (Hawkinson, 2011; Gugnani et al., 1994).

Following cumulative shreds of evidence that qualify the identified species of bats to be hosts or reservoirs of various viral genera of zoonotic importance, the interaction of human to these bats predispose them to risks of emerging and re-emerging infectious disease. The activities of guano collection, tin mining, tourism, storage and settlement within the bat habitats are at high risk of exposing the humans in zoonotic disease outbreaks.

Moreover, the intrusion of human activities in roosting sites was found to disturb the bats in their native habitat. In Murongo ward, atKyerwa district where tin mining dominated the mining industry, the miners were burning the used tires in abandoned mineshafts to re-establish their mining activities. This situation threatens the bats which mainly were ERB, to move for searching other sites. The stress caused to these bats might have increased the chance of shading the zoonotic pathogens to new areas. Additionally, these miners get into those mineshafts without taking precautions for infectious pathogens, especially, the use of PPE. From experience learned in Uganda, on MVD outbreaks linked to miners working in Kitaka Mine and tourists visiting Python Cave (Amman *et al*., 2021), these human-bat interactions in Kagera were an alarming indicator for MVD outbreak in Tanzania.

CONCLUSION

This study has shown a strong interaction between human - bat species that was strong enough to cause an epidemic. The collection and use of bat manure in Kagera have been practiced for long time, to the extant that it is considered to be a traditional. As the global is facing the effects of climate change, the dynamics of disease-causing pathogens which may result into more outbreaks of emerging and re-emerging diseases should be predicted. Hence, the risks for disease exposure should be minimized including visiting to bat habitats. Collecting samples from bats and confirming presence of MVD by Laboratory test would add weight to the evidence supporting bats as the source of this outbreak in Kagera region. However, by confirming the presence of bat species that have been confirmed as reservoirs of MVD and the presence of interactions between the cases of this outbreak and these bats further underscores the importance of this study in the body of knowledge. Hence, strengthen the evidence for the precautions and the need for the co-existence advocacy between humans and bats.

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PLANT SPECIES ABUNDANCE AND DIVERSITY IN LAKE MANYARA-NATRON ECOSYSTEM, NORTHERN TANZANIA

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ABSTRACT

Human societies have, for centuries, impacted and altered the natural environments through different land use practises. Though globally unsustainable land use practices are seen as one of the major threats to biodiversity conservation but this information is lacking in Lake Manyara-Natron ecosystem. Therefore, this study aimed at assessing the impacts of different land use types on plant species diversity, composition and structure in Lake Manyara-Natron ecosystem. Two different land use types (i.e. national park vs game-controlled areas) were compared. We employed nested plot techniques to collect the vegetation data in the area. Our results revealed a total of 177 plant species belongning to 41 families were recorded in the area. More herbs (47.2%), than grass (23.4%), shrubs (19.0%) and trees (10.4%) were recorded in the area. Also, only 8 plant species occur across all the land use types in the area. Additionally, Mto wa Mbu GCA had higher plant species diversity (*H*'=2.94) than Lake Manyara NP (*H*'=2.92) and Lake Natron GCA (*H'*=2.68) in the area. However, this finding is contrary to our prediction and the widely accepted perception that diversity is poorly managed in areas settled by people. However, Lake Manyara NP had higher shrub species richness per plot (n =19) than the Mto wa Mbu GCA (n = 16) and Lake Natron GCA (n = 9). Overall, the Mto wa Mbu GCA had more trees (n = 13) and herbs (n = 42) species richness than the other land use areas. These findings recomend for an urgent need to increase conservation efforts beyond the park boundaries especially that of the woody vegetation cover. Also, the management authorities should control the spread of any invasive shrubby species in the area.

Key words**:** *biodiversity, conservation, ecosystem, land use, plants, species*

INTRODUCTION

Land-use change remains the single most important reason for the loss of biodiversity as it leads to the conversion and destruction of existing ecosystems (Badu *et al*., 2007). Globally, land degradation has put the world's rangelands under intense pressure and reduced their capacity to provide vital services to those who solely depend on them for survival. Human population pressure and intensification of anthropogenic activities has been among of major drivers causing consequences of biodiversity loss and habitat fragmentation (Batáry *et al*., 2020). With current pressures on rangelands in the ecosystems, there is an urgent need to survey the present condition of rangelands. Such detailed surveys can identify where improvement programmes can be emphasised; whether it can be reseeding, stock control, sociological restraints or other management actions. Therefore, in conserving wildlife today, conservationists and wildlife managers are increasingly confronted by the challenges of understanding the dynamics that shape the vegetation cover and species diversity as wildlife habitat straddles across the land use divide (Zisadza-Gandiwa *et al*., 2013). It had been previously tested and found that areas adjacent to protected areas contribute to plant diversity in the greater ecosystem; hence conservation efforts should extend beyond the boundaries of protected areas (Halladay and Gilmour, 1995). However, little is known about the ecological consequences due to the increasing demographic pressure of human and livestock populations to the core wildlife area, therefore the aim of this study was to investigate the impacts of different land use types and contribute information for improving effectiveness conservation measures in the protected natural and semi-natural areas on human dominated landscape within Lake manyara-natron ecosystems. This study supports a significance conservation of plants and considers through direct protection of species and landscape in the context of protected areas.

MATERIALS AND METHODS

Study area

The study was conducted in Lake Manyara NP, Mto wa Mbu GCA and Lake Natron GCA (Fig. 1). These protected areas are located in Northern Tanzania's within Arusha and Manyara regions. Lake Manyara NP is located between Lake Manyara and the Great Rift Valley, was gazetted in 1960 and announced as a biosphere reserve in 1981 (Mwalyosi, 1991). It covers an area of about 325km^2, including about 200 km^2 covered by Lake Manyara which is a shallow alkaline lake acting as feeding ground for variety of bird species including flamingos and pelicans. Lake Manyara NP comprises a large variety of habitats from the groundwater forest a habitat to tree climbing lions, baboons and blue monkeys to vachellia woodland as well as open savannah.

Lake Natron GCA, is situated between the Ngorongoro Highlands and Serengeti plain, set at the base of Africa's only active volcano Oldonyo Lengai (Mountain of God). The protected areas lie in the beautiful Maasai Steppe and it's marked by the two volcanoes, mount Gelai and Lengai. Lake Natron itself is a soda lake that attracts an abundance of bird life including thousands of flamingos. The area comprises a pristine forest reserve and grass plains that extend into the Rift Valley which provide a suitable habitat for wildlife species. Between the Lake Manyara NP and Lake Natron GCA is interconnected with Mto wa Mbu GCA (Fig. 1).

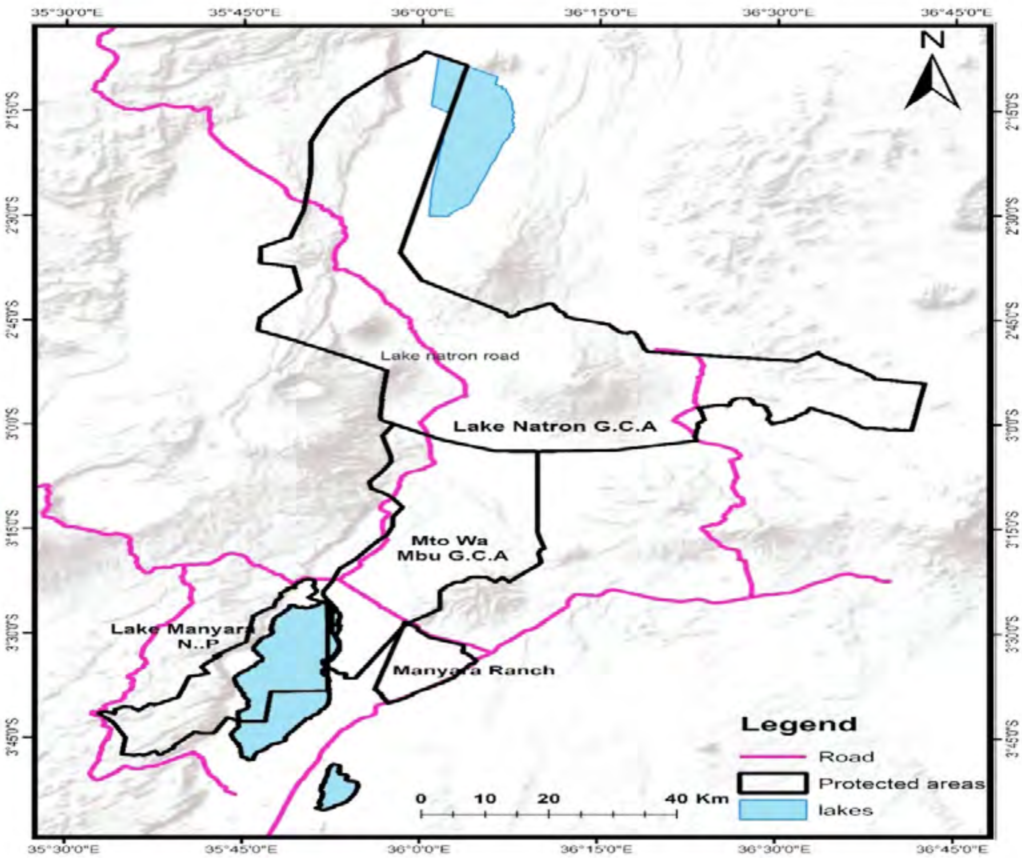

Fig. 1. Map showing the study areas (Lake Manyara National Park, Mto wa Mbu and Lake Natron Game Controlled Areas).

DATA COLLECTION

Vegetation surveys

Stratified random sampling technique was used to determine plots position and direction in the area by selecting one of two tossed written papers with a word either right or left and subsequent to that, sampling quadrats were placed systematically to collect the vegetation data. In this method nested plot technique was employed to collect the data in each transect. Transect had 5km in length and subdivided into five sampling sites with plots of 10m x 10m size which were placed at an interval of 1km apart, whereby each plot had three allocated sampling plots within from the right corner of the plot (1m x 1m) for herbaceous plants, (5m x5m) for shrubs and (10m x 10m) for tress. Two observers and two assistants worked together to sample all of the quadrat plots in each sampling site during the survey period. Herbaceous species cover (%) as well as height (cm) were measured within each quadrat of 1m x 1m and identified to the species level whenever possible. Those species that were not identified in the field were collected, pressed and brought into the herbarium for further identification.

Other information recorded included the date, transect name, GPS location and plot identification number, site code, plot code, GPS location, herbaceous sp., shrub sp. trees sp., their heights (cm), their % cover, average total height (cm), average % total cover, altitude(m) and level of disturbance. Also, disturbance intensity on habitat was assessed qualitatively with three categories: low, moderate and high as described by Averett et al. (2016). Low disturbance was defined as no to little visual impact to vegetation or soil from a recent disturbance (affecting < 10% of plot area). Moderate disturbance when vegetation loss and soil exposure affected is 10 to 40% of plot area. High disturbance where signs of removal of vegetation cover and exposure of bare soil on > 40% of plot area (Averett *et al*. 2016).

Data Analyses

The collected data were analyzed using the Statistical Package for Social Sciences (SPSS) version 14 for Windows (SPSS Inc., Chicago, IL, USA). Also, the collected data were summarised and tested for normality using the Kolmogorov-Smirnov test. The Shannon-Weiner (H') diversity index, Species richness (S), Evenness (J), and number of individuals plants (n) in each growth form of the vegetation communities sampled in different surveyed areas were calculated using PAST 4.2.0 version software (Hammer *et al*., 2001). Differences of the determined plant indices among the three protected areas were tested using chi-square at $p < 0.05$.

RESULTS

Our results revealed a total of 231 plant species belonging to 41 families. The vegetation communities were represented by Grass plant species: (2 families, n = 54, 10.4%), Herbs: (20 families, n = 109, 47.2%), Shrubs: (15 families, n = 44, 19.0%), Trees: (4 families, n = 24, 10.4%) in the area (Fig. 2)

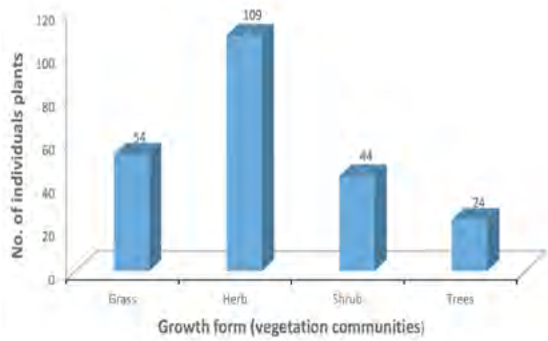

Fig. 2. The growth form of different vegetation communities showing the total number of individuals plants sampled in the area.

The findings have indicated that observed plant species were only occured in Lake Manyara NP (61 species), Lake Natron GCA (31 species) and Mto wa Mbu GCA (52 species) respectively. However, only 8 species occured in all the three areas. (Fig. 3).

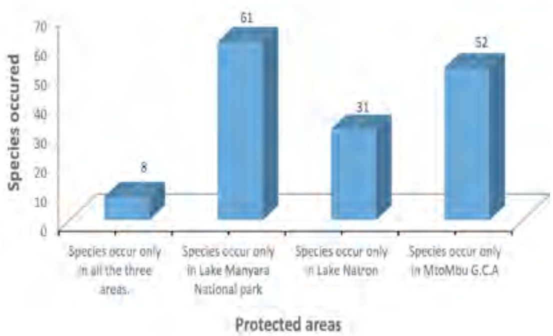

Fig. 3. The plant species occurred only among the three surveyed protected areas.

Additionally, among the three surveyed protected areas, Mto wa Mbu GCA had higher species diversity (H'=2.94) and number of individuals plants (180) than Lake Manyara NP and Lake Natron GCA (Table, 1).

Table. 1: Showing results of plant indicies from different surveyed areas.

Plant indices	Lake Manyara NP	Lake Natron GCA	MtoMbu GCA.
Species richness (S)	87	54	91
Individuals	172	110	180
Shannon_H	2.92	2.684	2.943
Evenness_e^H/S	0.2132	0.2663	0.2085

However, Lale Manyara NP had higher shrub species richness per plot (n =19, 43.2%) than the MTGCA (n = 16, 36.3%) and LNGCA (n = 9, 20.5%). Overall, the species richness of vegetation communities in Mto wa Mbu GCA was higher for herbs and trees (n = 42, 38.5%., n = 13, 54.2%) respectively, compared to the other protected areas. Moreover, evenness (J) of sampled plants species were observed similar for Lake Manyara NP and Mto wa Mbu GCA (Table, 1). The chi-square tests have indicated plant species richness did not differ in each growth form of vegetation sampled in the surveyed protected areas ($X^2 = 4.5$, p = 0.596) (Fig. 4.).

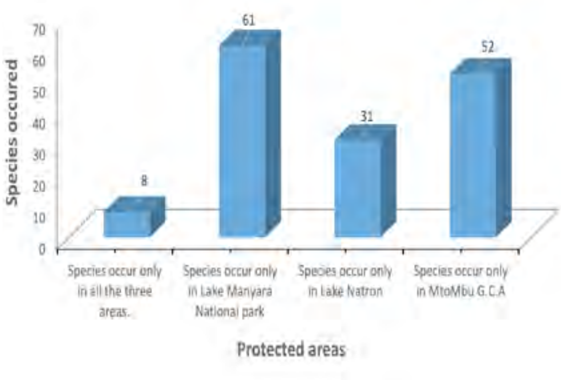

Fig. 4. The comparison of species richness of herbs vegetation communities recorded among the three surveyed protected areas.

DISCUSSION

Our finding revealed a total of 231 plant species belonging to 41 families found within the Lake Mayara-Natron ecosystem. Therefore, conserving natural areas and reducing biodiversity loss are core principles of most protected area management programmes (Masubelele *et al.*, 2013). Acoording to Masubelele *et al.,* (2013), protected areas managers across the world are confronted with a range of critical decisions in terms of assessing land use impacts on biodiversity. Additinally, Zisadza-Gandiwa *et al.*, (2013), reported that wildlife conservation in today's world is increasingly confronted by the challenges of understanding the dynamics shaping vegetation cover and species diversity as wildlife habitat straddles across the land use divide. One of the assumptions which have not been adequately tested is the protection of wildlife habitat in areas of different land uses surrounding protected areas (Zisadza-Gandiwa *et al.*, 2013). Therefore, this study tested this assumption in the Lake Manyara-Natron ecosystem and found that Mto wa Mbu Game Controllee Area had more trees and herbs species richness than the other land use areas especially the Lake Manyara national park. This finding confirmed that vegetation is the major component which contributing habitat heterogeneity in the landscape to support wildlife population and pasture for livestock production. However, it contradicts with the assumption that biodiversity is best managed in protected areas and other areas where land has not been fragmented due to human population pressure (Zisadza-Gandiwa *et al*., 2013). Again, our finding is similar to that of the previous studies which reported that conservation efforts of plant diversity should extend beyond the protected areas boundaries to achieve the long-term conservation of nature and its native biodiversity (Zisadza-Gandiwa *et al*., 2013). Similary the study by Mohammed et al. (2021) has reported that Dinder Biosphere Reserve showed poor natural regeneration in the disturbed sites where these areas have been exposed to anthropogenic disturbances. Previous studies have also revealed that vegetation cover dynamics was highly influenced by an increase of the anthropogenic activities especially outside protected areas (Halladay and Gilmour, 1995; Loth, 1999; Brown *et al*., 2001; Anderson *et al*., 2007; Mseja *et al*., 2020). Therefore, our finding indicates that, the Lake Manyara-Natron ecosystem was highly threatended by increasing human activities which have affected its natural vegetation communities. Again, it concurs with finding from the previous study which reported that increasing anthropogenic pressure and demand of natural resources use outside protected areas has implications to causes loss of biodiversity (Halladay and Gilmour, 1995). For example, JaneMary *et al*., (2001)., Morrison *et al*., (2016) reported that increased of agricultural activities and settlements have contributed to higher vulnerability of proteted area isolation and habitat loss which then posed threats on decline of landscape connectivity in the ecosystem, shrinkage of grazing patches due to changed vegetation communities in the area. Disturbances have been the main driving factors of increasing vulnerability on biological resources and might reduce ground cover across the landscape and support occupancy of invansive species (Critchlow *et al*., 2018) while on the otherhand affects vegetation regeneration and distribution of palnt communities (Dibaba *et al*., 2022). Therefore, quantifing the effects of anthropogenic activities on vegetations in the highly disturbed ecosystems was urgently needed to increase knowledge of their protection (Stohlgren *et al*., 1997) especially in the Lake Manyara-Natron ecosystem.

CONCLUSION AND RECOMMENDATION

The intense landuse have impacted and altered the natural environments and threatened the vegetation communities in Lake Manyara-Natron ecosystem. Land degradation remains the most important factor for the loss of biodiversity affect existing ecosystems services. With the current assessed plant species abundance, diversity and richness, such findings from the detailed surveys varied significantly and therefore suggested for the management authorities to increase conservation efforts beyond the park boundaries. Therefore, challenges of land cover dynamics across the landscape has been noted to increase an ecological ineffectiveness of protected areas as wildlife habitat loss has alarmed conservationists because of its potential implications for native biodiversity, movement of large herbivores and shrinkage of grazing patches between conserved areas. Moreover, anthropogenic pressure has increased the significance effects on the ground cover at large scale and cause the decline of landscape connectivity and changed the vegetation communities which support wildlife population and pasture for livestock production.

Our results support the study objectives to provides a valid and useful measures on maintaining the diversity of plant population, minimizing the high levels of anthropogenic disturbances and support ecosystem responses.

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WOMEN'S PARTICIPATION IN FOREST AND WILDLIFE MONITORING: THE CASE OF VILLAGE FOREST MONITORING IN WESTERN TANZANIA.

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ABSTRACT

Community participation in forest and wildlife monitoring is increasingly recognized as an important aspect of natural resource management. However, women's participation in various community activities are limited. The Jane Goodall Institute through USAID funding implemented a five-years project - Landscape Conservation in Western Tanzania (LCWT). One of the Intermediate Results of the Project was Increasing Monitoring of chimpanzee and their habitat. This paper aimed at sharing lessons learned from the process of recruiting Village Forest Monitors (VFMs) and focusing on female VFMs in monitoring of village forests and wildlife in Western Tanzania. The process of selecting VFMs involved sensitizing Village Councils who are responsible for nominating VFMs, then announcements were made in village centres and hamlets for villagers who wish to be VFMs to apply for the position. Applications were submitted to the Village Executive Officers and vetted by Village Councils, from the list, three names per village were brought to the Village Assemblies for the final nomination of the best candidates. The process enhanced obtaining of 108 VFMs of which 6 (5.5%) were female VFMs. The nominated candidates were offered the opportunity to join Pasiansi Wildlife Training Institute in Mwanza for a three-month course and then came back to their respective villages for monitoring their village forest reserves. From December 2021 to October 2023, data contributed by the six nominated female VFMs include 10,253 data submissions to the ArcGIS Online server whereby effort GPS points count for 9,352 (91%), threats 653 (6%), chimpanzee signs 13 (0.1%), other wild animal signs 164 (0.2%), other information 71(1%). Although female VFMs account for only 5.5% of all the recruited VFMs, their ratio of contribution to the monitoring of village forests was slightly higher than that of male VFMs. These findings not only shows that women are able to participate in forest monitoring but can also contribute useful, relevant, up-to-date, and actionable data for informed decision-making in NRM. However, in order to increase participation of women in forest monitoring, deliberate strategies need to be put in place to enhance participation of both men and women to achieve conservation outcome.

Keywords: Women, monitoring, forest, wildlife, chimpanzee

INTRODUCTION

Community participation in forest and natural resources management is increasingly recognized as important for achieving conservation outcomes (Ochola et al., 2010; Shackleton et al., 2002). Importantly, equitable gender participation (Ochola et al., 2010; Resurrection & Elmhirst, 2008; Faso, 2007; Meinzen-Dick *et al*., 2014; Aguilar *et al*., 2011; Ochola *et al*., 2010; Agarwal, 2009, 2010; Resurreccion and Elmhirst, 2008) is recognized as important to the success of forest management (Evans, K etal, 2019; Gurung and Setyowati, 2012; Sarin, 2001). The participatory monitoring process does not simply observe change; the very act of monitoring can create change (Guijt 2007; Evans and Guariguata 2008). Monitoring is widely believed to enhance accountability and strengthen local governance and is a possible catalyst for both strengthening good governance and encouraging the participation of women (Evans, K etal, 2019). Despite the importance of equitable gender participation in a success of forest management outcomes, women's participation in various community activities has been limited (Silvano, P., & Kweka, O. L. 2021). The Jane Goodall Institute through USAID funding implemented a five-years project known as Landscape Conservation in Western Tanzania (LCWT) of which, one of the Intermediate Results of the Project was increasing the Monitoring of Forests and Wildlife. The project was implemented as an integrated combination of Natural Resources Management, Land Use Planning, Governance, Livelihood, Family Planning, Environmental Education, Youth Engagement, Behaviour Change and Communications, and Gender Mainstreaming as crosscutting through all project activities. After implementing the project for the duration of five years (Nov 2018 – October 2023), we felt that it is important to shed lights on what has been achieved on female participation in community forest management, particularly forest monitoring.

Objective

This paper aimed at sharing lessons learned from recruiting and engaging Village Forest Monitors (VFMs) to monitor village forests with emphasize on equitable gender participation particularly on men and women. The paper brings the whole process of recruiting VFMs from sensitization meetings, applications, nominations, training, and the output. It also aimed at sharing the challenges encountered in the process and how the challenges were solved as lessons for improving on-going and upcoming projects on improving gender equity particularly on women participation in community forest and overall natural resources management.

MATERIAL AND METHODS

The process of recruiting Village Forest Monitors (VFMs) started with sensitization meetings on Village Councils. The facilitation teams for the sensitization meetings were led by district officers from Land and Natural Resources departments of the respective districts. The topics covered by sensitization meetings included presentations on the importance of forests including protection of water sources, control of soil erosion, regulating weather, facilitating rain formation, source of poles and timber for construction of houses as well as a source of charcoal and firewood for households. Also, implementation status of village land use plans, village forest monitoring experience sharing by the experienced VFM, qualifications of applicants for the position, and the proposed procedures for selecting VFMs. The sensitization to village councils was crucial because village councils are responsible for managing the process of recruiting VFMs.

Sensitization meetings were conducted in three phases for the 94 Village Councils that had no VFM or needed additional VFMs to monitor their Village Forest Reserves. Two meetings were conducted per day by one sensitization team. The morning session started from 10 am to 12 am and the afternoon session started around 2 pm to 4 pm.

Table 1. Phases of Sensitization Meetings to Village Councils

Phase	Time frame	Number of Villages	Districts
1	February 10th to March 09th 2020	20	Kigoma
		14	Uvinza
2	February 25th to March 11th 2021	11	Tanganyika
		25	Nsimbo
3	October 25th to November 11th 2021	20	Kigoma
		16	Uvinza
		2	Tanganyika
	Total	**108**	

In emphasizing participation of both men and women, during sensitization meetings we encouraged aspirants of both sexes and age (from young to adults) to apply for the positions. We also took on board female facilitators during sensitization process which also served as a motivation for female candidates to apply. The female facilitators came from district councils and JGI.

Plate 1. Sensitization meeting to the Vikonge Village Council in Tanganyika District of Katavi Region

The instructions for the entire process of VFM recruitment were shared with the village councils via the Village Executive Officers (VEO). The Village Councils took charge of managing the process of recruiting village forest monitors for their respective villages. The process involved several public address channels including public announcements, on notice boards, announcements in worshipping places, and via village meetings. The aspirants for the VFM position were instructed to send their application letters to their respective VEOs copying their hamlet chairpersons for information. After the deadline for the application, Village Councils convened for vetting and shortlisting of the applicants to three people per village. Then the names of the three shortlisted candidates were sent to the respective Village Assemblies for voting of best candidates by the village community.

After getting the names of the best candidates, the VEOs prepared cover letters attaching the application letters of the selected candidates, meeting minutes for the two meetings conducted in the process of nominating VFMs of each village which are: the minutes for the Village Council Meeting for shortlisting and Village Assembly Meeting for selection of the best candidate. After receiving the documentation, the District Executive Directors of the respective district councils communicated with the Jane Goodall Institute for capacity building to the selected VFMs on training and equipment support.

The Jane Goodall Institute through the USAID-funded project: Landscape Conservation in Western Tanzania (LCWT), supported capacity building for the selected VFMs by financing a three-month training at the Pasiansi Wildlife Training Institute (PWTI) in Mwanza. JGI also trained the VFMs in data collection protocols and tools (ArcGIS Surve123) customized for Western Tanzania. After completing the training, VFMs were offered equipment for field data collection while monitoring their respective village forests. The equipment includes smartphones installed the ArcGIS Survey123 data collection Application with a customized questionnaire specific for ecological data questions, mobile solar charging kits (WakaWaka Base 10), backpacks, and outdoor costumes (para-military uniforms) for use during forest monitoring.

After three months of training the VFMs came back to their respective villages to begin monitoring their village forest reserves and report to their village authorities.

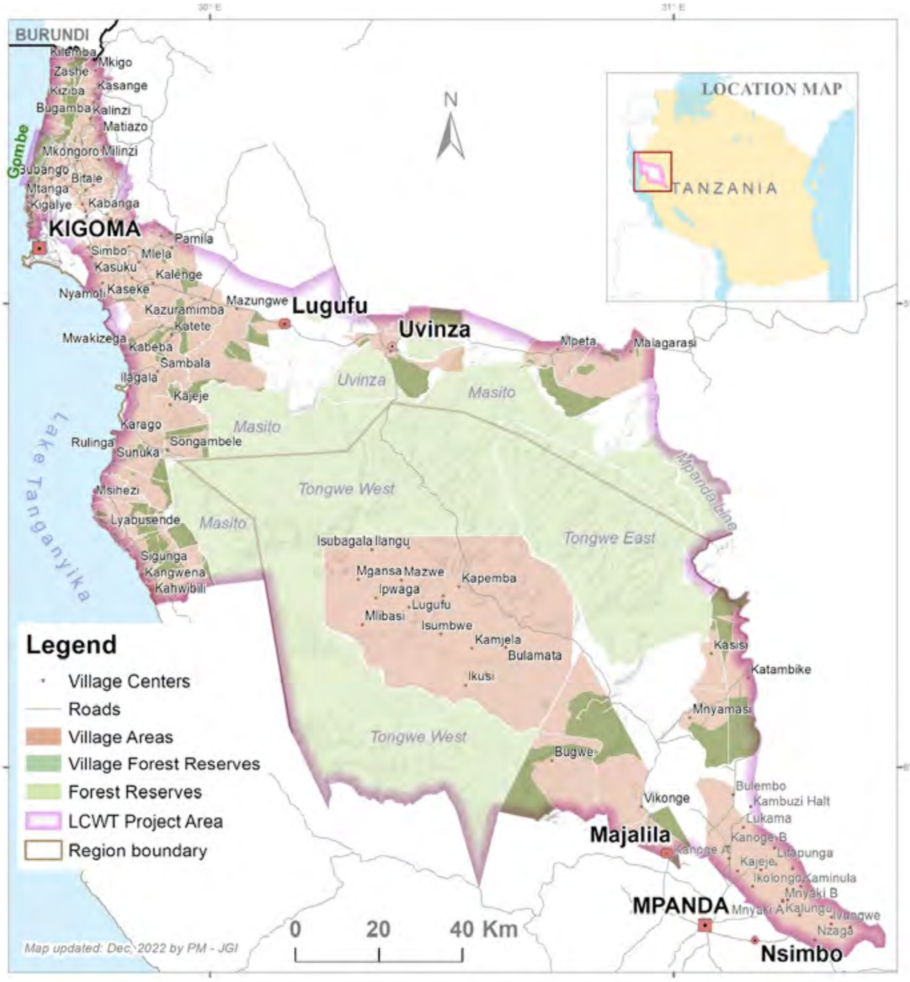

Plate 2. Location of Villages where VFMs were recruited from

RESULTS

A total of 108 VFMs were recruited of these, 6 (5.5%) were females under the age group between 18 to 35.

Plate 3. The six female Village Forest Monitors nominated during the LCWT Project

The findings indicate that from December 2021 to October 2023 (approximately two years), female Village Forest Monitors (VFMs) contributed a total of 10,253 data submissions to the ArcGIS Online server. These submissions include 9,352 GPS effort points—representing areas within village forests visited by the VFMs at 15-minute intervals—which accounted for 6% of the total data, equivalent to 2,338 hours spent on forest monitoring across six villages where these VFMs operate. This translates to an average of about 390 hours per VFM over the two-year period. Reported incidences included 653 records (4%) related to threats such as tree cutting, cultivation, fires, and cattle intrusion; 13 records (1%) of chimpanzee sightings; 164 records (4%) of signs of other wild animals; and 71 records (3%) of miscellaneous observations.

In reviewing the effort point data submitted over the two-year period, we observed that 149,593 points were recorded by the 108 Village Forest Monitors (VFMs). Among them, the 6 female VFMs—comprising 5.5% of all VFMs—contributed 9,352 points, or 6.2% of the total effort points. This indicates that, on average, female VFMs contributed proportionately more effort points than their male counterparts, suggesting they spent slightly more time in the forest than male VFMs.

Plate 4. VFM Amina Hussein with ArcGIS Survey 123 tool ready for village forest monitoring

Table 1. Data collected by the recruited VFMs for the duration of two years

Data category	Male FMs	% Male FMs	Female FMs	% Female FMs
Effort	149,593	94%	9,352	6%
Threats	15,001	96%	653	4%
Wildlife	4,262	96%	164	4%
Others	2,294	97%	71	3%
Chimp signs	1,282	99%	13	1%
All submissions	**172,432**	**94%**	**10,253**	**5.6%**

Plate 5. Trapped steenbok observed by the female VFM of Kirando Village on August 02, 2022

Plate 7. Illegal timber harvesting spotted and reported by the female VFM of Kirando Village on July 12, 2022

Plate 6. Velvet monkey reported by the female VFM of Nzaga Village on September 24, 2023

Plate 8. Charcoal bags observed by the Female VFM in Kirando Village on July 12, 2022

Challenges Encountered by Female VFMs

This study explored factors that may have prevented women from participating in village forest monitoring. In one Uvinza District Council village, the nomination process for a female VFM was challenging, as it faced disruptions by some village members. For instance, attempts to hold a village assembly to vote on candidates were repeatedly disrupted. Due to a 21-day deadline for VFM nominations, the Village Council ultimately decided to submit three shortlisted candidates (including one female) to the District Executive Director (DED) to select on behalf of the village assembly, ensuring the deadline was met. The DED chose the female candidate, a decision that sparked objections from one male aspirant, who formally appealed but later dropped the case, allowing the female VFM to join Pasiansi Wildlife Training Institute (PWTI) for a three-month program.

Gender stereotypes also posed challenges, as some villagers questioned whether a female VFM might marry and relocate.

"After I was shortlisted for the VFM candidature, some of the discussions in the village were on how the lady could become the VFM. Some village members questioned: What if she gets married to another village or another town or region?" (Interview with one of the female VFMs).

This stereotype, often rooted in traditional norms, portrays men as stable, career-focused figures while women are considered emotional, nurturing, and less reliable in professional settings. Such perceptions can hinder women's opportunities for advancement in various fields, including village forest monitoring. The belief that women may prioritize family or marriage over their careers can lead to their exclusion from roles that require commitment and leadership. Consequently, these stereotypes perpetuate a cycle of underrepresentation and limit the potential contributions of women to community conservation efforts, emphasizing the need for targeted interventions to challenge these norms and promote gender equality in all spheres of life.

DISCUSSION

Our data presented above shows that the process for recruiting VFMs brought 108 VFMs on board, but only 6 were female VFMs which accounts for only 5.5% of the 108 total recruited VFMs under the five years of the LCWT Project. Despite the low turnout, the 5% of female participation, still is a milestone since the beginning of community forest monitoring programs under the Jane Goodall Institute Tanzania way back in 2007, there has never been a record of that number of female VFMs. The history shows that there had been only two female VFMs who were engaged and did not stay long.

Although female Village Forest Monitors (VFMs) make up only 5.5% of the total monitoring team, their contribution to data collection is notable, surpassing that of their male counterparts. Female VFMs contributed 6.2% of the total effort points, which is 0.7% higher than expected based on their numbers alone. While this difference might appear small, it demonstrates that female VFMs are equally committed to monitoring their village forests. This finding aligns with literature suggesting that gender inclusion in forest management is crucial for achieving conservation outcomes (Evans, K etal, 2019; Gurung and Setyowati, 2012; Sarin, 2001).

Including both men and women in forest monitoring is essential, as the monitoring process not only tracks changes but can also drive positive community changes (Guijt, 2007; Evans & Guariguata, 2008). A predominantly male monitoring team risks excluding women from these transformative benefits, which are integral to effective forest management. Monitoring also fosters accountability and strengthens local governance, both of which are enhanced by including women. As equal members of the community, women should have opportunities to contribute to and benefit from forest management, supporting good governance and accountability in sustainable conservation practices.

CONCLUSION

Achieving conservation outcomes requires the meaningful participation of women in forest and wildlife monitoring. Through USAID funding, The Jane Goodall Institute, in collaboration with the district councils of Kigoma, Uvinza, Tanganyika, and Nsimbo, implemented the Landscape Conservation in Western Tanzania (LCWT) project. This five-year initiative supported local communities in establishing village forest monitors (VFMs) to oversee forest and wildlife health and report findings to village authorities. The project's results underscore the positive impact of including women alongside men in forest monitoring programs.

However, equitable gender representation remains a challenge, as recruitment efforts resulted in only 5% female VFMs, with 95% male participation. Despite this, the 5% female involvement marks a milestone, as it is the highest level of women's participation in forest monitoring since The Jane Goodall Institute began supporting these programs in 2007. Moreover, the 5% female VFMs made a substantial impact, contributing 6.2% of the monitoring data—an outcome that suggests female VFMs provided proportionately more data on forests and wildlife than their male counterparts.

The contributions of the six female VFMs (out of 108) highlight that women not only participate effectively in forest monitoring but also provide actionable, timely data critical for informed decision-making in natural resource management (NRM). As noted in the literature, community-wide participation in forest monitoring and NRM is crucial for program success; however, achieving balanced participation still requires targeted strategies. Based on our experience, effective strategies may include expanding communication channels within local communities to announce such opportunities, engaging female facilitators in sensitization efforts, and designating specific roles for women to enhance female representation.

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Thanks also to all village leaders, local communities, and existing VFMs who participated during sensitization meetings to share their unique experiences in the VFM role which was important for motivating the communities to jump into the opportunity.

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LEEWAY OF DEVELOPING WINE TOURISM IN TANZANIA: THE PROSPECTIVE OPPORTUNITIES AND CHALLENGES

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ABSTRACT

Wine Tourism is a growing global phenomenon that offers opportunities for wealth generation and social development in rural areas. However, Tanzania's viticulture sector has primarily focused on grape production and wine marketing, overlooking the potential of wine tourism. This study aimed to investigate the potential of Wine Tourism as a driver for community development and rural economic growth in Tanzania focusing on the wine-producing region of Dodoma. The study employed a combination of surveys, interviews, and case studies to examine the current status of Wine Tourism in Dodoma and its economic contribution to the region. Data were collected from key players in the industry, including tourism stakeholders, farmers, wine producers, wine traders, NGOs and policy makers. The results show very high potential for wine production in Dodoma and its role in attracting tourists to the region. The study underscores the need for improved promotion, infrastructure development, and policy support to harness the economic benefits of Wine Tourism. This is mainly due to the limited research on Wine Tourism in Tanzania that provide insights to compare with other destinations. Finally, we conclude that, Wine Tourism presents opportunities for community development, economic diversification, fostering entrepreneurship, and enhancing cultural exchange that can lead to sustainable development and job creation in wine value chain in Tanzania. Strategic planning, capacity building, and policy initiatives are crucial for the successful development of Wine Tourism in the region.

Keywords: Community Development, Viticulture Growers, Wine Routes, Wine Tourism, Tanzania

INTRODUCTION

Tourists have recently become interested in discovering regional cuisine that are linked to wine. This type of tourism is famously known as thematic tourism, which is an experience and insight into a particular way of life, linked to food. Wine and tourism (linked to local cuisine) allow tourists to appreciate a distinctive product; hence, the wine-producing region's economic growth will be promoted. In Africa, South Africa is leading in wine production in both quality and volume, followed by Tanzania by volume and with good wine quality. In Tanzania grape farming was introduced around 1938 by missionaries (Mpore, 2013; MAFS, 2006) and now Tanzania is ranked among Africa's top five producers, challenging South Africa's 350 years of dominance of the region's wine business (UN, 2013). Since its introduction, viticulture significantly contributed to household income (Safari et al., 2015; Kulwijila et al., 2018). According to the Dodoma City Council Agricultural Officer (DCC-AO) grapes are produced in over 3,426 hectares.

Wine Tourism development and active marketing of the Wine Tourism product is a relatively recent phenomenon (Hall, 1998). Wine Tourism is a niche tourism segment that involves individuals or groups visiting wine-producing regions and engaging in activities related to wine, including vineyard tours, wine tastings, cellar visits, wine and food pairings, and other experiences that provide insight into the wine production process, terroir, and local wine culture. It combines elements of gastronomic tourism, cultural tourism, and leisure travel, offering visitors an immersive and educational experience centered on wine (O'Neil & Palmer, 2020). Hall and Macionis (2018) defined Wine Tourism as visits to wineries, tasting rooms, vineyards, or wine festivals by tourists, who seek to sample and learn about wines and wine regions while having some experience. It is a form of specialty tourism that embraces a range of activities related to the celebration, consumption, and appreciation of wine. On the other hand Carlsen et al. (2010) call enotourism or vinotourism which involves visits to wineries and wine regions, typically including wine tasting and other activities such as winery tours, vineyard visits, and participation in wine-related events", and it is also part of the cultural, social, economic and environmental history of the wine-producing regions.

Wine Tourism can also be explained as 'a product-geography approach' which involves various components of the 'Wine Tourism product (outdoor dining; active participation in cultural and historical attractions or diverse regional peculiarities i.e. regional cuisine, architecture, heritage, scenic landscapes; visits to wineries; participation in some technological operations; education; wine tasting; wine-related cuisine; visits to vineyards and or wine museums; attendance to 'folk and more' programs, festivals and celebrations of wine' (Ivanova et al., 2015, Ferreira & Hunter,. 2017). Tanzania grape farming was introduced around 1938 but the concept of using this opportunity as a tourism attraction is still new. In this paper we are trying to suggest mechanisms that can make the country benefit and open Wine Tourism as a new product of attraction.

Research Problem Statement and objectives

Although the wine sub-sector in Tanzania didn't receive proper attention until around 2020, there is a significant contribution of viticulture and wine production to rural dwellers since its introduction in 1938s (MAFS, 2006) contributed significantly to household employment and income (Safari et al., 2015). Regardless of its potential, there is neither the existence of official Wine Routes / Roads nor Wine Tourism strategy and guidelines for operations.

Tanzania has been putting efforts into tourism diversification and set strategies to attract more tourists, extend the length of stay and increase expenditure based on other existing tourism products. But todate has not yet utilized its potential compared to other countries where cultural tourism, food and agri-tourism (Wine Tourism) has proven to be a significant contributor to the economy of wine-producing regions.

While, in Tanzania, tourism is the second largest after agriculture (Wade et al., 2001), still is mainly based on wildlife and beaches. According to Tourism Master Plan 2002 targets to increase activities as identified in the National Tourism Policy of 1999 such as conference, eco, sports and heritage / cultural tourism to date have not yet fully demonstrated and given their importance such as food and agri-tourism (Wine Tourism), among others. Wine Tourism is a new phenomenon worldwide yet and continuously flourishing, but in Tanzania there are no official Wine Routes to support Wine Tourism, and relatively few people and organizations are involved in this lucrative business. This paper aims to explore how "Wine Tourism," can be introduced to contribute to the rural economic development in Dodoma. It further explore how tourist Wine Routes can be created and developed by exploring the challenges which are faced by viticulture growers and wineries in the development of Wine Tourism. Then address the possible ways to overcome economic difficulties for viticulture growers through Wine Tourism development in Tanzania which is considered as an essential tourist destination and which has a long tradition in vineyard growing.

Theoretical framework

The development of a new wine region or Wine Tourism often involves the application of various theories and frameworks to understand and optimize the processes involved. These theories help guide strategies, enhance competitiveness, and create sustainable growth. Various authors illustrated their use in the context of wine regions and Wine Tourism development.

The Resource-Based View (RBV) theory suggests that a firm's competitive advantage and performance are primarily driven by its unique and valuable resources and capabilities. This theory aid to identify and leverage the unique attributes of the region, such as terroir, grape varieties, and winemaking expertise, to create a competitive advantage (Barney, 1991). Another closely linked is the Destination Competitiveness Theory (DCT). This theory focuses on the factors that influence the competitiveness of a tourist destination, including its natural resources, infrastructure, cultural assets, and marketing strategies. The theory helps identify and enhance the destination's competitiveness by improving infrastructure, offering unique wine experiences, and creating effective marketing campaigns (Crouch & Ritchie., 1999). The Innovation Diffusion Theory (IDT) explains how innovations spread and gain acceptance within a population. It identifies key adopter groups and factors influencing the adoption process. In a new wine region, this theory can be used to understand how new winemaking techniques, sustainable practices, or tourism initiatives are adopted by wineries and other stakeholders (Rogers, 2003). The Destination Image Theory explores how perceptions and images of a destination influence tourists' decisions to visit and their overall experiences. When developing a new wine region as a tourist destination, understanding and managing the destination's image is critical, this theory guides efforts to shape positive perceptions (Echtner & Ritchie, 2003). These theories provide valuable frameworks for understanding and guiding the development of new wine regions and Wine Tourism. The application of these theories can lead to informed strategies that promote growth, competitiveness, and sustainability in the wine industry.

THE HISTORY OF VITICULTURE AND TANZANIAN WINE PRODUCTION

Before independence

Vines were first introduced in 1938s by the Hombolo Roman Catholic Holy ghost Farthers from Italy near Kondoa District in Dodoma. The varieties grown included *Chenin Blanc, Syrah, Cabernet Sauvignon*, and a local variety named for a Dodoma sub-region, *Makutupora* red, the variety is named *Makutupora* depicting a district in which it is grown in Dodoma region, this variety is local dry red grape that prefers dry regions, and sandy soil with low humidity. It was grown for making wine for domestic consumption and religious use. Due to favorable weather conditions and fertile soil, a mild and breezy climate with temperatures ranging from 20°C to 35°C suitable for grapes, the country harvests twice a year in March and August/September. In 1957 Passionist Father Irioneo Maggioni, of the Bihawana Mission planted three vine seedlings as a trial which surprisingly grew rapidly to a commercial-scale farm (Wikipedia, 2021).

After independence

Vine plantation and wine production were limited to missionaries, but due to the success of the Bihawana Mission, the local government authority of Dodoma Urban District showed interest and invested in a four-acre grape farm at Dodoma Isanga Prison in 1961 which was quite successful and expanded into 5 acres. The national service camp in Makutupora was also inspired and joined the scheme in 1963 and started growing grapes in the village and around the area (https://en.wikipedia.org/wiki/Tanzanian_wine). In 1969 the Ministry of Agriculture established a vineyard state farm of 126 acres near the Vineyard Research and Training Centre (VRTC) Makutupora. The farm was later given to the Dodoma District Development Corporation (DODIDECO) which produced 31,280 liters of red wine in the first year (https://ntz.info/gen/n01506.html). Likewise, in 1969 the prison built a winery plant which was a sole purchaser of grapes for wine production in the country. The central government in 1979 was more inspired to boost local farmer's vine production, invested in a new company and created the Dodoma Wine Company (DOWICO), which supported local farmers through its created Makutupora Grapevine Research Centre to ensure best farming practices from vine production, maintenance, harvest and finally procured all grapes harvested for wine production (https://en.wikipedia.org/wiki/Tanzanian_wine) as well there was an opening of the Bihawana Winery. During the villagization period (1970-1976) there was a stable expansion of vineyards in both rural and urban in the Dodoma region as government authorities advised villagers to establish both communal and individual vineyards and villages competed in vineyard plantation and grape production. Individual farmers and villages became economically stronger and able to purchase village buses, trucks, and tractors, built modern houses compared to traditional tembe - a local hut with a thatched roof, and accumulated wealth on a communal basis. Gradually between the early 1960s and the late 1980s vine plantations became a dependable cash crop to peasants in Dodoma.

The vines plantation is purely organic grown without the use of pesticides, only protective measures are to spray twice yearly with copper sulphate to prevent rust and fungal infections. Inspirations by the missionaries, local government, and government institutions, the capital city of Dodoma was to have about 2,980 acres of vineyards in 1984. In 1986 wine production increased to 1.2 million liters as a result of the opening of another smaller winery called Capital General Manufactures (https://ntz.info/gen/n01506.html) (Wikipedia, 2021). Wine Tourism is likely to gain momentum in Tanzania, with wineries offering tours, tastings, and accommodation. This can become an attractive niche for tourists (Mosha & Hall, 2020) and can enhance the visibility and attractiveness of Tanzanian wines both domestically and internationally (Bruwer & Lesschaeve, 2018).

RESEARCH METHODOLOGY

The study was conducted in Dodoma region at Dodoma City and Chamwino District which are the principal commercial viticulture production areas in Tanzania (UN, 2013; LWR, 2016). The climate is semi-arid kind, low humidity weather and fertile sandy soil suitable for viticulture. The region is located between latitudes 4º and 8º South of the Equator and between longitudes 35º and 37º East of the prime meridian (Greenwich). This study used a cross-sectional research design which allowed data collection at a single point in time and suitable for a descriptive study and determination of a relationship between variables.

Purposive sampling and random sampling

The study was conducted during the period of March – October 2023. The random sampling started with population of 1370 growers from villages of Mpunguzi, Mbabala and Hombolo from Dodoma City and Mvumi Mission, Mvumi Makulu and Makang'wa from Chamwino district. Thereafter the purposive sample of 327 respondents were interviewed, which comprised viticulture growers, wine producers, tourism stakeholders, wine traders, agencies/NGOs, key informants and policy makers. A total of 240 viticulture growers were selected as per Conchran's (1974) formula as follows: $n = Z^2xPxq/e^2$, whereby n is the sample size; Z is 1.96 at 95% confidence level; P represents about 20% of the population of farmers in the area. An acceptable margin of error is 0.05, and q is a weighting variable computed as (1-P). Thus $n=1.96^2x0.2x0.8/0.05^2 = 245.86$. Sample size and valid responses were similar to the study by (Kulwijila et al., 2018). Likewise, the researchers randomly selected and picked 15 key informants and interviewed them. Later on, the collected information was summarized and processed using Statistical Packaging for Social Science (SPSS) program and analysed by simple descriptive statistics for quantitative data and content analysis for data collected from key informers or focus groups. The data were analyzed using descriptive statistics and multiple responses.

RESULTS AND DISCUSSION

Tourism in viticulture growers

Dodoma accounts for 1,910 viticulture growers in 3,426 hectares, however only 1,370 out of 1,494 growers were selected from the study area of Dodoma City and Chamwino whereby production is mostly dominated by smallholder viticulture growers harvesting about 3.5 tons per acre. Figure 1 show grape production trend from 2013 to 2021 indicating a huge variation of grape production hence generally this increasing trend indicates the promising future which is prerequisite for Wine Tourism development, in Figure 1 and sample pictutes in Photo 1.

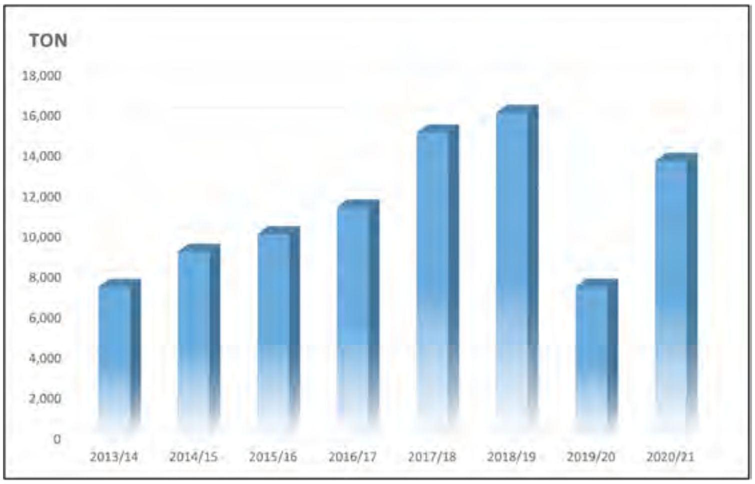

Figure 1. Trend Grape Production (tons) in Dodoma

Source: Dodoma Municipal City Council report, 2021

Photo1: Grape farms and fruits found in Dodoma region

Results in Table I indicates that winery industry was established since 1979 (9.1%) and continued to increase through 2021 (77.2%). This indicates that the industry is growing proportionally which is among crucial factors for Wine Tourism development of any wine region.

Table I: The winery survey (N=22)

Winery	Winery Survey	Frequency	Percentage
Ownership type	Sole proprietor	2	9.1
	Family	17	77.2
	Partnership	1	4.5
	Corporation/company with shareholders	1	4.5
	Other	1	4.5
	Total		**100.0**
Year Established	1979-1989	2	9.1
	1989-1999	3	13.6
	1999- 2021	17	77.2
	Total		**100.0**
Production in litres	Under 10,000 - small-scale	15	68.0
	10,000-50,000 - medium-scale	5	22.7
	Over 50,000 - large-scale	2	9.1
	Total		**100.0**
On-site visitors capacity	Under 5 pax - small-scale	15	68.0
	5 – 10 pax - medium-scale	5	22.7
	Over 10 - large-scale	2	9.1
	Total		**100.0**

Table II presents challenges faced by viticulture growers in the Dodoma region, which are closely linked to Wine Tourism in the area. Results indicated several key issues such as absence of official Wine Routes (75.8%), insufficient capital for high-quality hospitality and tourism investments (52.5%), limited access to wineries and viticulture growers (49.3%), and a shortage of quality restaurants and accommodation facilities (41.1%). Additionally, 72.5% of growers lack knowledge of grape handling techniques, prompting large-scale wineries such as ALKO Vintages and CETAWICO to intervene during the harvest to ensure the quality and hygiene of grapes for wine production. Wineries also face significant challenges, including a shortage of high-quality grapes (87%) and poor visibility of local wines in the domestic market, particularly within tourism and hospitality sectors (85.4%). Furthermore, locally produced wines suffer from limited international recognition (97.1%), a trend similarly reported by Kulwijila et al. (2018). On the other hand Tanzania Agricultural Research Institute (TARI) commented that, poor visibility of Tanzanian wine is due to few varieties, however is currently researching on 9 new more varieties to be introduced after being certified by Tanzania Official Seed Certification Institute (TOSCI). Besides wineries suggested that the establishment of official Wine Routes, connected to existing natural tourism attractions, could help to increase visitor flow and extend their length of stay, a point resonated by Hall C.M. (2012) and Grossling (2016), who highlight the ability of Wine Routes to attract more visitors to vineyards and wineries.

Table II: Wineries and viticulture growers challenges and accessibility in Dodoma region

Growers accessibility	**Rate (%)**
Access to Wineries and Viticulture growers	49.3
Presence of road sign	8.6
Lack of quality restaurant and accommodation facilities	41.1
Poor customer service and professionalism	27.3
Lack of capital for quality Hospitality and Tourism investment	52.5
Lack of cultural facilties (art, crafts)	35.5
Insufficient grape of good quality to wineries	87
Lack of knowledge of grape handling techniques by viticulture growers	72.5
Poor visibility of local wine in the domestic market	85.4
Poor international recognition of locally produced wine	97.1
Lack of an official Wine Routes	75.8

This study noticed that viticulture sites in Dodoma is mainly scattered and located within Dodoma City and Chamwino District. Visiting them, you have to organize your transport. For example visiting the Hombolo district is a journey of about three hours (due to untarmacked rough road which is even worse during rain season), you need to board a public transport from the city center which is expensive even by public transporst, can costs up to TZS 13,400 for a round trip. Visiting Chinangali II grape project, the road is well accessible, however is expensive for domestic tourist, it can costs up to TZS 4,400 for a round trip from the city center. This factor hinders visitation, as also cited by Fernandes, 2021study in destination such as Portugal where food and wine tourism is prominent, whereby respondents commented that, location of viticulture growers and wineries being scattered and far from the city center, yet with underdeveloped roads limits number of visitors, hence demotivating hospitality and tourism investors in the area. This indicates that the geographic distance among visited wineries in Dodoma poses further challenges for initiatives to attract “numbers” of travelers, as was noticed too by Getz and Brown 2006 in the emerging wine region of Western Australia.

Tourism in wine processing

Generally, since establishement of wine industry in 1979 in Tanzania, results in table I indicated that most (77.2%) of wineries were newly opened between 1999 to 2021 and are sole proprietor/family run and owned. Of these, 86.4% & 91% were small-medium-scale respectively while only two were large-scale 9.1%, one is family owned and the other one is a corporation with partnership. Similar case was found by Getz and Brown 2006 in the emerging wine region of Western Australia (Okanagan valley) that 69.6% comprised of small-scale while only one wineries can be considered large. Importantly, studies by Safari et al., 2015 and Kulwijila et al., 2018; reveals that since inception of wine industry its contributuion to the local community is evedent, as likewise cited by Woldarsky & Genny-Dennis., 2019 study on wine tourism in regions famous for wine production, such as France, the United States, or South Africa where respondents considered the age of the industry as not only significant to them but its contribution to the local. Hence results reflect the development of winery and the general state of a newly emerging winery region in Dodoma. According to the DCC-AO, there are 29 wineries including two large-scale wine producers (ALKO Vintages and CETAWICO, which was formerly known as DOWICO). The 22 visited wineries opinion regarding visitation in (Table III), revealed that, the interest to visit (demand) is high (70.3%) from June which is a high season through December during college holidays when students are assigned projects to do. Visitation slightly increases to 75.8% within high season due to wine festival event carried for a week yearly in September in Dodoma, which also bring other businesses.

Wine Tourism has been increasing worldwide not just because of tourist requirement but due to proof of supporting Community Development (Sigala. M., 2014) due to creation of other local services resulting into “spillover effect” due to development of local tourism and other products (Keen, 2004; Besser and Miller, 2004). Further commented by ALKO Vintages “the wine festival event used to be organized by wineries each September yearly since its inception in 2018 - 2021 but since the government has taken over this initiative in 2022, there were no more events since 2022-2023; yet it is evident the event attracts more people wishing to create memorable experience since the festival is associated with competitions where winners get labeled prizes (opener, glass, embossed bottle of wine) while others visit for purchase and winery tour especially tour companies; visitation aim to impart experience creates memory and, therefore reflects Wine Tourism experience”; hence if wine festival event continues will support the government on efforts to increase tourist to 5 million by 2025. However, respondents highlighted that the frequency of visit is prominent but couldn’t state figures, yet visitors’ capacity were clearly stated in table I, whereby small-scale wineries can handle under 5 pax (68%), medium-scale under 10 pax (22.7%) while large-scale wineries can handle more than 10 pax (9%) with group limitations to 15-30 pax at per due to space, but notably to exhibit hygienic practices while offering experiential guided tours.

Table III: High demand periods for visitors

Visitors to winery processing	**Rate (%)**
Winter and summer season - High Season of tourism June - December and Wine Festival	75.8
College holidays - High Season June - December	70.3
College days - Weekdays	59.7
College days - Weekends	19.3

The results suggest that, despite the seasonal nature of visits, there is considerable demand for vineyard and winery tourism, highlighting the need for developing a Wine Tourism framework and promotion strategies to attract more local and international tourists. It is essential to connect wineries with wine-related institutions (Simoes, 2003; Telfer, 2001) and integrate them with existing tourist attractions managed by both the public and private sectors. This aligns with Getz’s (2000) recommendation that Wine Routes should be incorporated into broader national and regional frameworks, involving both public and private sector management (Telfer, 2001).

Table IV indicates winery participation in Wine Tourism (visitation, guided tour, tasting, purchase, dining). It was noted that (23.3%) of wineries are open to the public wishing to experience the grape-wine production process, restaurant services, tasting and cellar door purchases, although small-medium-scale wineries did not have wine tasting facility. Only large-scale wineries (100%) offer a complete visitor experience while very few wineries offers Tourism and hospitality services open to public (6.9%). Results indicates some elements of existence of Wine Tourism in Dodoma region, however with limited facilities which limits or affects visitors total experience of a wine region. Similar case was observed by Getz and Brown 2006 that, emerging wine regions lag in the development of hospitality and tourism facilities hence they may need more time to develop.

Table IV: Wineries involvement with Wine Tourism and hospitality services

Wineries	Frequency	Percentage[1]
Wineries open to public (visitation, guided tour, tasting, purchase, dining	7	23.3
Wineries cellar door sale	22	100.0
Tourism and hospitality services open to public (hotel, restaurant, local bars	2	6.9
Wine Festival Event participation	22	100.0
Other related business event participation (wholesellers, liquer store, art and crafts merchants)	2	6.9
Other recreational activities within (Meeting & Event spaces)	1	3.3
Other recreational activities within (hiking, biking, walking, horse riding)		N/A
Restaurants nearby and linked to wineries visitation	1	3.3
Other non-related entrepreneurs with wineries/Tourism and Hospitality	15	70.0
Wineries offering complete visitor experience	2	100.0
Hospitality and Tourism facilities event participation		N/A

([1]Total is more than 100 due to multiple responses)

Moreover, it can be urgued that reluctancy in Wineries involvement with Wine Tourism and hospitality services might be highly attributed to the dispersed location of wineries and viticulture growers observed in Table II and lack of official Wine Routes linking wineries to other attractions in Table V.

Wine tourism with other tourism attractions in dodoma region

Dodoma's strategic advantage lies in its central location as the capital city, bordered by four key regions and easily accessible from Tanzania's popular northern tourism circuit. This makes it well-positioned to connect with the less-explored Western and Southern Circuits, which have untapped tourism potentials.

The presence of viticulture and wineries is a critical factor in attracting tourists to the area, hence supporting the growth of Wine Tourism. Although Wine Tourism is currently practiced in Dodoma region, it is still in its infant stage and cannot yet predict when it will reach maturity.

According to the Ministry of Natural Resources (MNRT) official and URT-OR TAMISEMI report (2019) Dodoma region has multitude of tourism attractions which suits to be linked with other attractions in the the country. Despite of this, still many areas need improvements to make Wine Tourism successful. In Table V, majority of respondents (96.9%) indicated that if Wine Tourism will be linked with cultural practices will have positive impacts both socially and economically. Developing Wine Tourism strategy (95.4%), partinership among public-private sectors (100%), partnership among wineries (91.2%), more specific promotion of region for Wine Tourism (99.6%) and production of new wine varieties (98%), are important for improving the business of the winery tourism. Other factors at lesser scale is developing wine routes (86.4), More promotion of region in general 89.6% and Partnership among wineries and other entrepreneurs 89.8%.

Table V: Other areas to be improved for Wine Tourism success factors

Wineries	**Frequency**	**Percentage[1]**
Linking wineries to local cultural practices (food, customs and tradition)	21	96.9
Linking wineries to local restaurant selling wine	17	75.8
Wine Route development	19	86.4
Wine tourism strategy development	21	95.4
Partnership among wineries	20	91.2
Partnership among wineries and other entrepreneurs	20	89.8
Partnership among public-private sector	22	100.0
Recreational facilities/activities within/nearby	14	65.2
Higher quality accommodation at winery/nearby	13	60.1
Restaurant/cafe at winery/nearby	16	72.2
Fine dining/restaurants in area	17	76.5
Regular Wine festivals and events in area	18	83.9
Special events at winery	14	63.5
More promotion of region in general	20	89.6
More specific promotion of region for wine tourism	22	99.6
More promotion of winery as tourist attraction	16	72.2
Produce new wine varieties	22	98.0
More promotion of wines	18	79.6

Note: ([1]Total is more than 100 due to multiple responses)

All wineries interviewed (100%) partner during Wine festivals to promote Wine Tourism (Table VI). However partnership was less in other wineries (13.3%), in cultural festivals, MICE events, communication agencies, restaurants, accommodation, tour companies and other package organizers (3.3%), hence indicating the dominance of independent travelers as well individualism of wineries since they all partner to promote only through wine festival event. This reflects a need for improvement to have packaged services needed for more and better-quality investment efforts in Dodoma, as it enhance the destination's competitiveness (Crouch & Ritchie., 1999) and facilitate offering of competitive and educational experience centered on wine (O'Neil & Palmer, 2020).

Table VI: Partnership in Wine Tourism promotion

Partnership	Frequency	Percentage[1]
Other wineries	3	13.3
Tour companies	1	3.3
Cultural festivals	1	3.3
Wine festivals	22	100.0
MICE events	1	3.3
Communication agency	1	3.3
Sport events	0	0.0
Transport operators	0	0.0
Accommodation and restaurant suppliers	0	0.0
Other package organizers	1	3.3
Please specify	1	3.3
None	1	3.3

Note: ([1]Total is more than 100 due to multiple responses)

Barrier to develop Wine Tourism in Dodoma region

Barriers that impede development of Wine Tourism in Dodoma region are presented in Table VII. Most significant expressed by 49.3% of the respondents is poor government support, little emphases has been placed by the govement to promoted Wine Tourism. It is more likely that there is no strategy for this type of tourism. Others include lack of long term development plan as repoted by 19.6% of the respondents and limited interest from public bodies to promote Wine Tourism.

Table VII: Barriers to the development of Wine Tourism in Dodoma region

Barriers	Rate (%)
Poor Government support	49.3
Lack of long term development plans	19.6
Lack of interest from public bodies	17.1
Insufficient promotion of existing tourism products	4.2
Insufficient research to explore new tourism product	7.3
Poor infrastructure linking tourism products	2.5

CONCLUSION AND RECOMMENDATION

Tanzania being the second largest producer of wine in Africa have very high potential of developing stable and profitable Wine Tourism in Africa. However, wine sub-sector efforts has primarily focused on grape production and wine marketing, overlooking the potential of Wine Tourism. Wine and tourism (linked to local cuisine) allow tourists to appreciate a distinctive product; hence, economic growth of wine-producing region's through cellar doors sales and new business opportunities associated with Wine Tourism; notably when linked with other attactions on nothern and southern tourism circuits. This study conclude that to date, Tanzania is a sleeping giant in Wine Tourism, hence concerted effort by all stakeholders to revive this sectors is vital.

This study recommends the following:

- There is a need to promote this little known Wine Tourism in the country,
- Develop partinership among public-private sectors,
- There is a need to link wineries with other social and cultural practices like food, customs and tradition to draw more visitor to winery region,
- Foster partnership among wineries,
- Produce more varieties of grapes and wine for diverse consumers,
- Developing Wine Routes,
- Effort to develop Wine Tourism strategy.

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