Nomination of Nyungwe National Park as World Heritage Site
Complementary information on the questions raised in the interim report by IUCN (25.01.2023)

Observations	Request	Comments
● Regarding criterion (ix), the Panel has noted a number of knowledge gaps, such as on the dynamism between closed-canopy and open-canopy forest, between the vast mountain bamboo thickets and the various types of surrounding forests (see nomination dossier), the role of fire, and the effects of the loss of keystone species. ● In regard to criterion (ix), the Panel also noted that feasibility studies for the proposed reintroduction of Savannah Elephants and Grey Parrots were undertaken very recently. ● The field evaluation mission also understood that there are biomonitoring reports for Nyungwe National Park, which are not included in the nomination documentations.	In order to assess the suggested potential of the nominated property to meet criterion (ix), please provide further information, if available, on 1. recently published research or current research regarding: a. the dynamism between closed-canopy and open-canopy forest,	*No scientific studies have ever been published about the dynamics between closed-canopy and open-canopy forest or between bamboo thickets and surrounding forests in the Nyungwe Forest. Only in Kenya these subjects were studied (e.g. Agnew, 1985; Bussmann & Beck, 1995a, 1995b; Grimshaw, 1999; Janzen, 1976).* *However, several people have known about the Nyungwe Forest for more than 50 years. In addition, there are aerial photos from 1956 and 2011 and recent high-resolution satellite pictures on Google Earth. All these observations show that:* *(a) the boundary between the closed-canopy and open-canopy forest is changing very little or at least extremely slowly; it was only temporarily affected in the mid-mountain forests (2000-2600 m a.s.l.) of the eastern part of the Nyungwe Forest block by the fires of the 1990s. Currently, most of these areas are covered with secondary forests.*

Observations	Request	Comments
	b. the dynamism between the vast mountain bamboo thickets and the various types of surrounding forests,	*(b) As for the bamboo thickets, their evolution is very simple: they die each time a bamboo clump blooms, and this is a natural phenomenon. No quantitative study has been done, but according to the aerial pictures the extent of bamboo thickets has been reduced by about 60-70% since the 1970s. Also, the extensive homogenous bamboo thickets of the central part of the forest block are now fragmented. The same is happening in Echuya Forest in Southern Uganda. A mapping of the vegetation is proposed, but the results will not be available before 2024 and it will say nothing about the vegetation changes. All what could be done is a comparison between ancient aerial pictures and recent ones in some selected areas.*
	c. the role of fire, and the extent of native liana in areas previously damaged by fire, including whether this is considered invasive,	*(c) Similarly, there are no publications concerning the pseudo-lianas Sericostachys tomentosa and S. scandens in the Nyungwe Forest. Contrary to what happens in Kahuzi-Biega NP in DRC and Kibira NP in Burundi (Habonayo et al., 2019; Masumbuka et al., 2012; Zihalirwa et al., 2020), the distribution of these plants has not changed significantly since 1970, and they do not invade burned areas. However, the Kahuzi-Biega and the Kibira forests are much more disturbed than the Nyungwe Forest. Moreover, their distribution is obviously not related to fires or elephants. Indeed, they are abundant in valleys where there have never been fires or elephants and are absent in ridge forests where elephants used to be until 1975. In fact, these*

Observations	Request	Comments
	d. the effects of the past loss of keystone species, such as Elephants and Leopards.	*pseudo-lianas are found only in lower-montane, open-canopy forests.* *(d) There are no studies on the impact of elephants or leopards. The elephants inhabited only very limited areas of the forest block (edges of peat bogs and ridge forests) and, before 1948, they only visited the Nyungwe Forest during the dry season. Their permanent presence in the Nyungwe Forest was a result of human activities in the Rusizi plain in Burundi. As for leopards, these were probably everywhere but in very low densities and the goldminers had more impact on the mammal fauna than the leopards.*
	2. the latest versions of the feasibility studies for the reintroduction of Savannah Elephants and Grey Parrots,	*To date, we have the versions below:* ● *The latest pre feasibility study for the reintroduction of elephants can be accessed here: http://bit.ly/419JEc1* ● *The latest version of the feasibility study for the reintroduction of grey parrots can be accessed here: http://bit.ly/3YTWVE6*
	3. the latest biomonitoring reports for Nyungwe National Park.	*Regarding the biomonitoring reports produced by WCS, we were never able to obtain them, and they were not published officially. Only that of 2002 has been published (Plumptre et al., 2002), but it is not very useful: it has been carried out in two months of fieldwork in the middle of the dry season and gives a strongly biased image of the Nyungwe Forest. Its bird*

Observations	Request	Comments
		list contains many misidentifications and is, therefore, useless; the mammal list is very incomplete. As for the population estimates, the most recent were not published, and the Nyungwe Management Company has decided to organize its own assessments. *The 2 following documents have remained draft and were never published:* ● *Biodiversity survey of Nyungwe National Park: 2009 -2014 (http://bit.ly/3KqJkiW)* ● *The status and trends of populations of Chimpanzee (Pan troglodytes) and other mammal species in Nyungwe National Park, Rwanda (http://bit.ly/3YRQW2j)*
Regarding criterion (x), the Panel has taken note of some potential inconsistencies in the species lists provided, e.g. the numbers mentioned in the description within the main nomination document do not appear to match the species lists in Appendix B of the nomination dossier.	In order to ensure accurate data underpins the potential of the nominated property to meet criterion (x), 1. Please could the State Party provide a single updated list of species confirmed to be present in the nominated property? 2. Please note if any of these are introduced species.	*The lists on appendices are correct and mention the introduced species. Only the figures in the text need to be corrected.* *The updated list for Appendix B is available at http://bit.ly/3XSIUoy* *Mammals (p. 44): 115 species, 1 introduced (Rattus rattus), and 4 locally extinct (Loxodonta africana,*

Observations	Request	Comments
		Syncerus caffer, Hylochoerus meinertzhageni, and Panthera pardus). *Birds (p. 46): 318 species, 0 introduced, and 0 extinct.* *Reptiles (p. 47): 47 species, 0 introduced, and 0 extinct.* *Amphibians (p. 48): 31 species, 0 introduced, and 0 extinct.*
The Panel has also noted that the nominated component parts of Cyamudongo and Gisakura Natural Forests are separated from the main Nyungwe National Forest component part by areas of other land-uses, including tea plantations and settlements.	Please could the State Party indicate 1. its willingness, and to what extent it could be feasible to develop functional corridors for the movement of wildlife between these nominated component parts to improve the connectivity of the nominated property, and 2. how these would relate to the boundaries of Nyungwe National Park?	● *The 3 components (Main forest, Cyamudongo and Gisakura) are inclusively gazetted as part of Nyungwe National Park and their management is also inclusive* ● *The long term plan as reflected in the Long Term Sustainability Strategy (http://bit.ly/3kdOeW7) is for the creation of wildlife corridors linking the 2 forests (Cyamudongo and Gisakura) to the main forest.* ● *It is important to note that the Cyamudongo forest has been isolated from the Nyungwe forest since the end of the 19th century or the very beginning of the 20th century (120-140 years). However, these two forests were naturally separated by the Bugarama rift, an ancient fault that linked the Rusizi plain to Lake*

Observations	Request	Comments
		Kivu. Hence, the floras of Cyamudongo and Nyungwe are significantly different at the same altitude. This explains why, despite its small area, the Cyamudongo forest is home to many species that do not exist in the Nyungwe forest. Only monkeys probably wandered from one forest to another. Establishing a corridor would moreover be very difficult socially—many families would have to be moved—and would have very little biological significance.
The Panel further noted that an international road currently crosses the nominated property, but that much of the traffic on this road is expected to be diverted in future to an upgraded road, which passes to the north of the nominated property.	1. Please could the State Party provide updated information on the timeline for this proposed diversion and explain if and how it will be ensured that the traffic crossing the park will be reduced to a minimum? 2. Furthermore, please indicate if it would be possible to reinstate a closure of the road that crosses the nominated property for traffic during the night?	*The road passing through Nyungwe forest is of great importance for the socio economic life of the population around and as an international link to the neighbouring Democratic Republic of Congo and Burundi. However* ● *The road Muhanga - Karongi - Nyamasheke, once fully rehabilitated, is likely to reduce the traffic through the forest by absorbing part of the direct fleet between Kigali and Nyamasheke or Rusizi. The rehabilitation works have started, under the supervision of the competent Agency and the remaining 40 kms are expected to be completed by mid 2024* ● *There is a process underway to regulate the traffic in the main forest with the intention to reduce the speed and noise hence reducing to the strict minimum possible accidents in the*

Observations	Request	Comments
		forest and any form of pollution. Proposed measures include, but are not limited to, installation of speed limit road signage and speed control cameras. ● *A sustained awareness on the use of the road inside the forest has been undertaken by the park authority and involves different categories of users: transport agencies, local communities and law enforcers*
The Panel noted that the General Management Plan for the nominated property expired in 2021. The field evaluation mission understood that a Draft Sustainability Plan was in the process of being finalised, and should be approved in March 2023, fulfilling the role of the expired General Management Plan.	Please could the State Party confirm that this information is correct, and also provide a copy of the latest version of the Sustainability Plan and the firm schedule for its final approval and subsequent implementation?	*The existing general management plan for Nyungwe National Park had to cover the period of 2012 - 2021. After the constraining period of COVID-19 pandemic, the management of the park has worked on a long term sustainability strategy (LTSS), which is expected to be approved by the board in March 2023. Some aspects of it are being implemented. A copy of the final draft can be accessed at http://bit.ly/3kdOeW7*
The Panel has noted furthermore that Nyungwe National Park borders Kibira National Park, located in the State Party of Burundi.	Please could the State Party indicate the current situation regarding exchanges on conservation matters between Nyungwe National Park and Kibira National Park, including any arrangements, which support the integrity and protection of the southwestern part of the nominated property?	*There is a cooperation arrangement between Rwanda and Burundi for the management of the Nyungwe-Kibira landscape, and a Memorandum of Understanding (accessible at http://bit.ly/3klV9fR) was signed in September 2008. Joint activities across the border have included coordinated patrols, training sessions and regular meetings of park managers among others. A joint strategic plan was drafted in*

Observations	Request	Comments
		2009 but its implementation was temporarily frozen. Fruitful resumption is expected in a near future *A recent economic valuation of transfrontier protected areas of the East African Community (2022) highlighted the economic importance of the Nyungwe - Kibira complex among others and its planning has involved experts from both countries. The valuation report can be accessed at http://bit.ly/41h9TNt*

The reintroduction of African Grey Parrots: Restoring Rwanda's native wildlife

A detailed proposal, February 2021

Rwanda Wildlife Conservation Association

World Parrot Trust

1. Background

Grey parrots, *Psittacus erithacus,* occur in the moist tropical forests of West, Central and East Africa with a range stretching from eastern Côte d'Ivoire to Kenya. Population declines, primarily due to over-exploitation for the international pet trade and habitat loss, have led to the species recently being up-listed to Endangered on the IUCN Red List of globally threatened species. In 2016 they were transferred to Appendix I of CITES, the highest level of protection available under the convention, prohibiting international trade in wild specimens for commercial purposes.

In East Africa only a handful of populations persist, scattered across forest fragments in Uganda, Kenya, Tanzania, Burundi and Rwanda. In Rwanda, Grey parrots are only known to occur in Nyungwe forest but are thought to have undergone a sharp decrease prior to 1990 (Dowsett 1990). Surveys have produced few records for the species in recent years, reports of small groups of 2-5 individuals occasionally seen in south-eastern Nyungwe (Mulindahabi pers. comm. 2014; Ntoyinkima pers. comm. 2015). There is an additional record from 2007 from Kibira forest, an area of forest in Burundi adjoining with Nyungwe (Mulindahabi pers. comm. 2014). There are no recent records for the species elsewhere in Rwanda.

2. Preferred Habit

Grey parrots occur in moist forests throughout tropical Africa. Although the densest populations may occur in relatively pristine areas, they use a variety of modified habitats including farm-bush and oil palm plantations. They even occur in some urban areas such as in Kampala and Kinshasa. As strong fliers, they may use a variety of different habitats within a landscape.

3. The Illegal Trade

Trapping for the pet trade has been a major threat to wild populations of Grey Parrots. Although Rwanda has not exported wild Grey Parrots for commercial purposes since it became a signatory to CITES, illegal and historical trade have likely impacted populations (Dowsett 1990). The trade has a long history. There are some written accounts from the 19th Century of large numbers of Grey Parrots being moved eastwards for export from the east coast. We know from old paintings that this species was in trade to Europe and likely Asia for centuries before that. Together with the loss of habitat these processes have led to their current endangered status.

In recent years, it's likely parrots have been smuggled across Rwanda from DRC to be exported from Uganda or Kenya. There was a seizure at Kigali airport in 2006 of Grey Parrots reportedly sourced from DRC.

4. The World Parrot Trust (WPT)

The World Parrot Trust was founded in 1989 and is a registered charity in the UK, USA, and Canada. It specialises in wild parrot conservation, captive parrot welfare, and eliminating trade in wild parrots. The WPT has supported the reintroduction of many parrot species around the world, involving thousands of individual birds confiscated from trade.

Key WPT Staff for this project are Dr. Rowan Martin, Africa Program Director; Cristiana Senni, Bird Trade Specialist; James Gilardi, Executive Director.

5. Rwanda Wildlife Conservation Association (RWCA)

Rwanda Wildlife Conservation Association is a non-governmental organisation registered with Rwanda Governance Board (RGB) in 2015. Its main objective is developing a holistic, multi-disciplinary approach to critical conservation issues in order to create sustainable solutions for some of Rwanda's most critical conservation issues. Founded and run by Rwandans who come from and understand local communities and their challenges, this is done primarily through activities that protect wildlife and natural habitats, engage and educate local communities and improve livelihoods, raise awareness of conservation issues, build the capacity of young Rwandese conservationists and disseminate high quality research and evaluation.

RWCA has proven its success in implementing a reintroduction programme with the endangered Grey Crowned Cranes, addressing the illegal trade and working with local communities. Its team of dedicated staff and volunteers are ready to use their expertise and local knowledge to work in partnership with WPT and RDB on the reintroduction of Grey Parrots.

6. Nyungwe Management Company (NMC) and African Parks (AP)

Nyungwe Management Company (NMC) is an entity, under the umbrella of African Parks (https://www.nyungwe.org), entrusted by the Government of Rwanda since October 2020 to fully manage Nyungwe National Park and progress its conservation, tourism and community practices.

African Parks was started in 2000 in response to the loss of protected areas and wildlife in Africa, pioneering a public-private partnership model. By entering into long-term agreements with governments to manage and finance one or more of their national parks, African Parks takes on direct responsibility for the day-to-day management of the area, all activities in it and managing all threats to it. AP's ultimate objective is to ensure that the unique landscapes under our management, and their spectacular wildlife, are secured and valued forever. For this to happen, each park has to be ecologically, socio-politically and financially sustainable.

African Parks identified five key management pillars to achieve this desired impact: Law Enforcement, Biodiversity Conservation, Community Development, Tourism & Enterprise, Management & Infrastructure. This typically involves the following activities: implementing an effective law enforcement programme by equipping, training and managing rangers, restocking the park with founder populations of indigenous species, building necessary park infrastructure – including roads and housing, managing relationships with neighbouring people and implementing community projects to ensure that they benefit from the park's existence, and developing tourism and associated business enterprises to develop an income stream for the park and a mechanism for socio-economic development and poverty alleviation.

7. Reintroduction Programmes

Grey Parrots have recently been given full protection under CITES, ending the legal trade. Creating opportunities to start new populations in their historic range is a sensible and progressive next step that will reverse the long history of exploiting parrots for pets, feathers, and food.

Parrots are generally slow to reproduce and rarely recolonise areas from which they've been driven to local extinction. Reintroductions provide a unique opportunity to encourage their recovery in select areas where they can be well monitored and protected. By preparing birds for release and supporting them through a soft release procedure, most parrot species, including Grey Parrots, tend to make the transition to the wild with success, and often initiate breeding in the wild within months of the release itself.

In Tanzania an ambitious release programme initiated in the early 2000s has seen the establishment of a thriving population of Grey Parrots on the island of Rubondo and has acted as a springboard for the establishment of the species in other areas of North-Western Tanzania. In Uganda a group of Grey parrots seized from trade and released in Kibale forest National Park is still thriving and regularly seen today.

8. Why Rwanda?

Grey parrots have undergone rapid declines in parts of their range due to over-exploitation and forest loss. Rwanda is one of several countries that have lost their Grey Parrot populations and there is the possibility of establishing new populations in their historic range. Conditions are particularly favourable for a successful restoration project in Rwanda because areas of suitable habitat are well protected, there is little risk of further illegal trade (no recent history), and Rwanda has experience and expertise from successful reintroduction projects with other species.

9. Advantages for Rwanda

This project could lead to many advantages for Rwanda including:

- Allow Rwanda to add another species to the growing list of successful reintroductions in Rwanda, aspiring to restore Rwanda's native wildlife.
- Rwanda could quickly take the lead within the East African region for successful Grey Parrot reintroductions and develop a model from which other countries can learn.
- There are few places in Africa where this species can be seen by tourists reliably, easily and safely so it can be a unique opportunity for Rwanda's tourism.
- Will support the Rwanda Development Board, National Avitourism Strategic Plan for Rwanda, boosting Avitourism. Grey Parrots add colour and sound for all ecotourists.
- Few living Rwandans have ever seen a Grey Parrot in the wild and many do not even know they once existed there
- As large frugivorous birds, parrots can be important agents of seed dispersal contributing to forest regeneration and promoting biodiversity by connecting forest islands (Baños-Villalba et al. 2017).

10. Potential risks

Disease risks are mitigated through quarantine, precautionary medication and disease screening. The long-term impact on the ecosystem is likely to be very positive, rather than negative and aligns with goals to restore ecosystem services provided by forests.

11. Resources needed

Although the resources needed for this project are minimal, it is important to consider the following:

- Training for Rwandan staff and volunteers
- The building of a simple soft release enclosure
- Quarantine costs
- Food during the soft release
- Staffing costs for monitoring during the soft release and post release monitoring

12. The role of WPT

WPT will identify parrots needing to be reintroduced, ensure that quarantine and disease screening has been complete in the holding country. WPT will also complete the necessary export permits. WPT will assist where needed in training Rwandese personnel to ensure the capacity is in place to receive the parrots and manage the soft release. A member of WPT will visit Rwanda to assist and train local staff. WPT will also be available for advice and consultation as and when needed during the process of reintroduction.

The approach of WPT is to ensure the project goes forward in a way that's positive for the birds and conservation, and will always look to and defer to the local partners infinitely greater expertise on the realities of what can and can't work within the country context.

13. The role of RWCA

RWCA will use its contacts and experience to organise the infrastructure needed for the project. RWCA will liaise closely with both WPT and RDB to ensure that the project is successful and fits with the expectations of both organisations.

RWCA will make the necessary site assessments with guidance from RDB and ensure all necessary approval, permits and consultations with the Rwandan government take place.

RWCA will make use the staff and volunteers who have gained experience through the Grey Crowned Crane project and will recruit other staff and volunteers if necessary. RWCA will plan to conduct post release monitoring work and community engagement work and when necessary look for additional funds for this work if possible.

14. The role of Nyungwe Management Company (NMC)

African Parks (AP) – Nyungwe Management Company will provide logistical support for staff and related aspects of the project such as the monitoring of the Greys when they reach Nyungwe. The budget allocated to supporting this activity during the whole year 2022 is $12,000. Moreover, the sustainability and success of this repatriation will greatly depend on the good general protection of Nyungwe National Park in general which is the mandate of NMC in the next 19 years.

15. The role of RDB

RDB will ensure that all necessary approval and permits have been given and provide governmental backing for the project. RDB will allow access to the site chosen and use the opportunity to promote tourism, particularly Avitourism, in line with RDB's Avitourism Action Plan. RDB will also organise and

participate in within-country media opportunities as a way of raising awareness and promoting conservation and tourism.

16. Potential Release Sites

Rwanda is a very small country and it is likely that any restored population of Grey Parrots is going to eventually move around a lot as the have the ability to fly long distances and will locate its own preferred areas for foraging, roosting, and breeding. They may commute daily or move seasonally across borders into Uganda, Burundi, or DRC. Generally, released birds stay close to the release site for the first few years, but after 5-10 years, that will likely change, especially if the population grows.

While it is crucial for there to be ample habitat at the release site, it's also important to know that parrots in general and this species in particular is very flexible in its diet, movements, and use of habitat. This means that whichever site is chosen, the birds will likely fare well in terms of habitat, particularly if they are supported through a 'soft release' process.

17. Site Assessment

Four potential release sites have been identified within Rwanda. They all have National Park Status and are protected areas for wildlife.

A number of criteria have been selected that are important for the reintroduction of Grey Parrots and each site has been assessed on the basis of multiple criteria which primarily concern the availability of suitable habitat, the existence of adequate infrastructure to support the programme, tourism potential, possibilities for post release monitoring and potential for positively engaging local communities.

We identified three potentially suitable sites.

a) Nyungwe National Park

Nyungwe is the largest area of forest in Rwanda. There are historical sightings of Grey Parrots in the forest which indicate it is suitable habitat and altitude. It is a very dense forest with few open areas and although it is easy to walk in using the trails, it has many inaccessible areas and it would be hard for post release monitoring due to less access and visibility. Nyungwe National Park probably ranks high for African Grey Parrots reintroduction because of the infrastructure, existing tourism and park personnel such as rangers who can help with post-release monitoring.

b) Gishwati/Mukura National Park

Gishwati forest would be another best site for post-release monitoring as it is easy to walk around and track released birds and is a relatively small forest fragment. This is a new national park so starting this project would increase the visibility of the park and enhance tourism. In addition to the already existing endangered chimpanzees and the endemic golden monkeys, the Grey Parrot reintroduction would be a unique ecotourism opportunity. Grey Parrots may help in forest restoration. There are no confirmed records of Grey Parrots in Gishwati forest although a few individuals, including experts working in the area have sighted African Grey Parrots nearby. The forest is at the high end of the altitudinal range recorded for the species.

c) Cyamudongo Forest

This forest also provides a good habitat with plenty of food. It is also dense forest with less open areas which would make the rehabilitation and release challenging. As a fragmented forest, it is small compared to Nyungwe. There might be a high level of illegal activities and human activities in this forest due to its fragmented nature.

18. Next steps

This proposal will serve as an opportunity to discuss this conservation opportunity and the next step would be to address and concerns or questions and decide whether it is something Rwanda would like to happen. If Nyungwe Management Company (NMC) and RDB agree to proceed, WPT will assist in bringing Grey Parrots to Rwanda. RWCA and WPT already have an MOU that outlines each organisation's responsibilities.

Other steps that need to be considered are:

- CITES export and import permits
- selection of release site
- training of Rwandese staff
- transport logistics
- quarantine in Rwanda
- construction of release site
- staffing / monitoring considerations

execution of the release

17. Future of the released Greys population

After the release of the first group of Grey Parrots, post release monitoring will need to take place and a thorough evaluation of the successes and challenges of the project. There is the potential for further reintroductions at same or different sites if and when other groups of Grey Parrots are confiscated. Raising awareness among the Rwandan population would also be useful to ensure that no Grey Parrots are captured for the pet trade. Engaging local communities around the release site will also be useful. There will also be opportunities for writing up the project for dissemination so that the project can act as a model for other similar projects in neighbouring countries.

MEMORANDUM OF UNDERSTANDING (MoU)

BETWEEN

L'INSTITUT NATIONAL POUR L'ENVIRONNEMENT ET LA CONSERVATION DE LA NATURE (INECN)
Gitega, Burundi

AND

THE INSTITUTION IN CHARGE OF PARK CONSERVATION IN RWANDA
Kigali, Rwanda

ON THE TRANSBOUNDARY COLLABORATION REGARDING CONSERVATION AND PROTECTION OF KIBIRA NATIONAL PARK (BURUNDI) AND NYUNGWE NATIONAL PARK (RWANDA)

September 2008

I. INTRODUCTION

Kibira (Burundi) and Nyungwe (Rwanda) National Parks in the Albertine Rift are contiguous forming the largest protected forest block in East Africa. While Nyungwe National Park is the largest protected area in Rwanda, Kibira National Park holds the largest mountainous forest ecosystem under protection in Burundi.

This transboundary ecosystem is invaluable both locally and internationally. Biodiversity is unique with many endemic species. Its conservation value has been recognized by many international organizations namely Conservation International (CI), the World Wide Fund for Nature (WWF), the Wildlife Conservation Society (WCS) and MacArthur Foundation (Chicago, USA).

Despite the level of connectivity and similarity in terms of threats, Kibira and Nyungwe National Parks have been managed as distinct and individual units. For years now, this lack of collaboration between managers of both Protected Areas has been a real hindrance to conservation efforts on both sides of the border.

In a bid to ensure sustainable conservation of the Nyungwe-Kibira Landscape (NKL) and benefit from the advantages of transboundary collaboration, the National Park Authority in each country, the Wildlife Conservation Society (WCS), a partner of both institutions and acting as facilitator, initiated since 2006 a number of collaborative actions as a prelude to developing this MoU.

Both institutions intend to formalise this cooperation through the signing of a Memorandum of Understanding (MoU).

II. MEMORANDUM OF UNDERSTANDING

PREAMBLE

This memorandum is established on a mutual agreement basis and signed between the institution in charge of Park Conservation in Rwanda, based in Kigali, Republic of Rwanda, and the Institut National pour l'Environnement et la Conservation de la Nature (INECN) in Burundi, based in Gitega, Republic of Burundi, (after which hereby referred to as « Parties»),

GIVEN THAT both parties are mandated by their respective Governments to manage the protected areas and in doing so, are entitled to engage in collaboration with other institutions at national, regional and international levels to ensure sound conservation of nature and the environment;

GIVEN THAT both parties share common objectives in the area of conservation of protected areas and they wish to join efforts for the protection of Kibira and Nyungwe National Parks;

RECOGNIZING the principles of sovereignty and integrity of their States;

MINDFUL for people's welfare and sustainable development through natural resource management;

CONSIDERING that both parks provide habitat to many animal species that move constantly and freely from one country to the other across political boundaries between States;

HIGHLIGHTING the importance of the Kibira-Nyungwe Landscape for its role in the regional hydrography, its ecological value as well as its level of biological endemism, which is one of the highest in the Albertine Rift region;

AWARE of the advantages of the transboundary management for conserving transboundary resources in general and migratory species in particular;

RECOGNIZING the necessity of protecting the environment and nature, especially this precious forest ecosystem shared by Burundi and Rwanda with services rendered to local and international communities;

CONSIDERING the similarities in threats affecting Kibira-Nyungwe landscape, socio-cultural links and the cross border nature of some actions by local communities contributing to the destruction of this ecosystem;

CONSIDERING their common objectives in ensuring sustainable Park Conservation, both parties hereby agree as following:

ARTICLE 1:
OBJECTIVES OF THE TRANSBOUNDARY COLLABORATION

The objectives of the transboundary collaboration in the Kibira-Nyungwe landscape are as follows:

a. Cooperation in the conservation of biodiversity, natural resources and associated cultural values, in the research, monitoring and ecotourism for both parks in the two countries;

b. Promotion of landscape conservation through planning and better management of the two protected areas ;

c. Commitment for planning, sustainable use and management of natural resources in the transboundary region in order to reduce the threats affecting these protected areas ;

d. Improvement of trust, understanding and cooperation between the two parties, and other players for the sustainable conservation and peace in the region ;

e. Working closely together to enhance and share resources, skills, experience and good practices in the area of management and

research, ecological monitoring, for a sound and effective management of biodiversity and cultural values ;

f. Promotion of the advantages derived from conservation and sensitization for benefit sharing at the national and international level;

g. Improvement of understanding of the importance of conservation within partners and the general public;

h. Promotion of biodiversity conservation aiming at reducing poverty and conflict resolution in the region.

ARTICLE 2:
COOPERATION

Parties agree to:

a) Ensure that Kibira and Nyungwe National Parks (hereafter referred to as "Parks") put into consideration the objectives of the transboundary collaboration listed under Article 1 of this MoU;

b) Consult each other, provide mutual assistance and support required for achieving transboundary collaboration objectives ;

c) Collaborate on the development of a strategic plan for the transboundary collaboration in order to make it official.

ARTICLE 3:
IMPLEMENTATION OF THE TRANSBOUNDARY COLLABORATION

Parties agree to:

a) Put in place a Secretariat for the transboundary collaboration comprising the relevant authorities as well as technical personnel to be nominated by the parties and a Facilitator from WCS

b) The secretariat inter alia, will guide and steer the development of the above mentioned strategic plan for transboundary collaboration with facilitation from WCS.

ARTICLE 4:
SECRETARIAT OF THE TRANSBOUNDARY COLLABORATION

The mission of the Secretariat for the transboundary collaboration to be set up under this MoU is to:

a) Develop a work plan for activities and meetings, rules and procedures governing the Secretariat ;
b) Develop a strategic plan for the transboundary collaboration ;

c) Coordinate all activities initiated under the transboundary collaboration between the two national parks of Kibira and Nyungwe ;
d) Organise regular exchange and consultation meetings for the parties' representatives based on schedules established and validated in advance;
e) Formulate proposals and advice regarding ongoing or planned activities within the two protected areas;
f) Adopt measures in conformity with this MoU aiming at promoting integration and collaboration in the management of the two parks.

ARTICLE 5:
ISSUES RELATED TO PROJECTS AND FINANCES

Parties agree that:

a) This MoU can be enriched with projects and work plans or any other addendum describing more specifically activities to be implemented or any other document required by the cooperation programme. Projects and plans may be attached to the MoU as appendices by either Party. However they must be approved by both Parties.

b) In order to fulfil their agreement in conformity with terms of this MoU, signatory parties will strive to get funds from their respective institutions or from other sources to develop a strategic plan for the transboundary collaboration and implementation of all the activities listed in the transboundary collaboration.

c) The allocation system of funds from different interventions will be determined by a consensus agreed between the two institutions;

d) Execution of funds under this MoU will be carried out by the Secretariat for the transboundary collaboration.

ARTICLE 6:
RESPECT FOR LEGISLATION IN FORCE IN THE COUNTRY

This MoU will never be interpreted as derogation to any law in force in either country of origin of the Parties or any other agreement between Parties.

ARTICLE 7:
CONFLICT SETTLEMENT

Any conflict rising from misinterpretation or implementation of this MoU shall be amicably resolved through mutual consent after consultations and negotiations.

ARTICLE 8:
COMPETENT AUTHORITY

The authorities entrusted to guarantee the implementation of this MoU are:

(a) The Director General of the Institut National pour l'Environnement et la Conservation de la Nature

(b) The representative of the institution in charge of Park Conservation in Rwanda.

ARTICLE 9:
FOLLOW-UP

Each year and for the first time twelve months after signing this MoU, The Secretariat will report to the Parties on activities and achievement during the one-year period. This report will be used as reference document for planning activities for the next year.

ARTICLE 10:
AMENDMENT

This MoU can be amended following a written agreement between the Parties.

ARTICLE 11:
TERMINATION

This MoU can be terminated by either Party by notifying the Secretariat of the transboundary collaboration. This must be done in writing stating their intention to terminate the MoU three months in advance.

ARTICLE 12:
ENFORCEMENT

This MoU takes effect immediately after signing by the duly authorised representative of each party.

Duly authorised for the Institut National pour l'Environnement et la Conservation de la Nature au Burundi (INECN)

- [Name]: NTUNGUMBURANYE Adelin
  DIRECTEUR GENERAL

[Signature]

[Date] 09/09/2008

Duly authorised for the Institution in charge of Park Conservation in Rwanda

- [Name] Rosette Chantal Rugamba

[Signature]

[Date] 9/9/2008

For the Facilitator (WCS)

- [Name] ASSENGIYUMVA BARAKAMUYE

[Signature]

[Date] 03rd Sept 2008

This MoU is signed and sealed by Parties in duplicate, one copy in French the other one in English. Both copies are authentic.

PROTECTING EAST AFRICA'S NATURAL CAPITAL
THE COST OF INACTION

A synthesis of the economics of natural capital in East Africa

January 31, 2022

EAST AFRICAN COMMUNITY

USAID FROM THE AMERICAN PEOPLE

Maasai man, Tanzania

PHOTO: PATRICK NEASE

Submitted by: Nick Oguge, Chief of Party, Environmental Incentives, LLC
Submitted to: Chihenyo Kangara, Contracting Officer's Representative, USAID Kenya/East Africa

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This document was produced for review by the United States Agency for International Development. It was prepared by Environmental Incentives and Anchor Environmental Consultants (Pty) Ltd. for the Economics of Natural Capital in East Africa Program.

Front cover photo: *Wildebeest crossing the Mara River during the annual great migration. Every year millions will make the dangerous crossing when migrating between Tanzania and the Maasai Mara in Kenya. Credit: Jane Rix*

Version 1.3

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ACRONYMS

AWF	African Wildlife Federation
CBD	Convention on Biological Diversity
COVID-19	Coronavirus Disease 2019
CBNRM	Community-Based Forestry Management
DRC	Democratic Republic of the Congo
EAC	East African Community
GDP	Gross Domestic Product
GCSA	Gaborone Declaration for Sustainability in Africa
IUCN	International Union for the Conservation of Nature
LVEMP	Lake Victoria Environmental Management Program
KPAC	Kidepo Protected Area Cluster
MRB	Mara River Basin
MW	Megawatt
NBSAP	National Biodiversity Strategy and Action Plan
NCA	Natural Capital Accounting
NGO	Non-Governmental Organization
PES	Payment for Ecosystem Services
PRB	Pangani River Basin
RSS	Revenue Sharing Scheme
SDG	Sustainable Development Goal
SEEA-EEA	System of Environmental-Economic Accounting – Experimental Ecosystem Accounting
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations
UNFCC	United Nations Framework on Climate Change
USAID	United States Agency for International Development
WMA	Wildlife Management Area

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PHOTO: HENDRIK CORNELISSEN

Zebras, Tanzania

i. INTRODUCTION

East Africa's natural capital – its iconic wildlife, forests, grasslands, and waterways – spans across national boundaries, industry sectors, and habitat types, delivering ecosystem services on which many stakeholder groups are mutually dependent. That's why valuing and protecting East Africa's natural capital must occur not only at the site or sectoral level, but rather at the landscape level. With landscape-level thinking, stakeholders can begin to view themselves as part of an interconnected system and understand how they both impact and benefit from shared natural assets.

United States Agency for International Development (USAID) and its EAC partners undertook this first of its kind study to determine the value of natural capital in four priority, transboundary landscapes. The findings will enable stakeholders to make more informed decisions about how to govern natural resources in the same manner as other forms of capital, such as produced goods and services.

While continued research is required, we now have foundational data on the relative value of various ecosystem services in a key portion of East Africa. This landscape-level data is enabling stakeholders to work across boundaries – whether political, social, or geographical – on solutions for protecting their shared natural wealth and enhancing their collective well-being.

In the past six months, this draft report has undergone a peer review process. Also, the team has convened hundreds of stakeholders at the landscape, national, and regional levels to review and validate the data, as well as develop a draft action plan. Under the guidance of the East African Community and Partner States, the action plan will be finalized by early 2022.

1. THE ECONOMIC CASE FOR PROTECTING NATURAL CAPITAL

NATURE: THE FOUNDATION FOR HUMAN WELL-BEING

The benefits humans receive from the natural environment are vast - ranging from food and livelihoods to dean air and water to resilience to climate change and disease. Most natural resources are renewable and could be infinite if we consumed them at a sustainable rate. Hence business leaders and policymakers must treat it like any other form of capital: failing to "spend it wisely" will inevitably diminish social, economic, and human well-being over time.

In the past few decades, there has been a global push to quantify the economic and intrinsic value of the world's natural capital, so that the full benefits of conservation are not only better understood but can be factored into policymaking at every level of society. This means going beyond traditional market assessments, which value nature only by those goods extracted and marketed - such as fish, livestock, honey, and timber. These valuations fail to account for the negative impact of extracting these goods, such as air and water pollution, which are costly to mitigate (Burke, 2013). It also means factoring in the other human and economic costs of degrading ecosystems - including reduced resilience to climate change, storms, floods, and disease. Integrating data on natural capital into budgets and decision-making processes as standard practice will enable policymakers, businesses leaders, and natural resource managers to steward resources more responsibly and sustainably.

Knowing the economic value of nature's benefits can make its contribution to livelihoods and economies visible, enabling smarter, more sustainable policy decisions. Governments can account for nature's role in national and regional economies, as well as in human well-being. Business leaders can manage risks in their supply chains by understanding their impact on and benefits from a larger ecosystem. And communities that rely on natural resources for their livelihoods can better understand the value of these resources, as well as the importance of sustainable practices to ensuring long term prosperity.

At a global level, the United Nations Convention on Biological Diversity has already called on leaders of all nations to protect natural capital by adopting a 2030 target to fully conserve at least 30 percent of the ocean and 30 percent of land areas and inland waters through effectively and equitably managed, ecologically¬representadve, and well-connected systems of protected areas.

The malachite kingfisher sitting on a reed

PHOTO: KAREL BARTIK

Natural capital
The world's stock of natural assets, which include geology, soil, air, water, and all living things.

Ecosystem
Community of interdependent living organisms, including wildlife and wildlife habitat.

Ecosystem service
Any positive benefit, direct or indirect, that ecosystems provide to humans.

HOW DO WE ASSIGN VALUE TO NATURE?

Assigning value to natural capital can be a complex undertaking. But a common approach among economists is to consider the range of services that ecosystems provide humans.

The System of Environmental Economics Accounting - Experimental Ecosystem Accounts (SEEA EEA; UN 2014) typically classifies ecosystem services into three categories - provisioning, cultural, and regulating (see Figure 1).

- **Provisioning services** are the harvestable resources supplied by ecosystems, such as wild foods, raw materials, and forage for livestock production.
- **Cultural services** are the ecosystem attributes (e.g., beauty, rare species) that give rise to the "use values" gained through any type of activity ranging from adventure sports to birdwatching, religious or cultural ceremonies to just passive observation, or the "non-use values" gained from knowing that they exist and can be enjoyed by future generations.
- **Regulating services** are the functions that ecosystems perform that benefit people in surrounding or downstream areas or even distant areas. These services include water flow regulation and water quality amelioration, carbon sequestration, crop pollination, and soil retention.

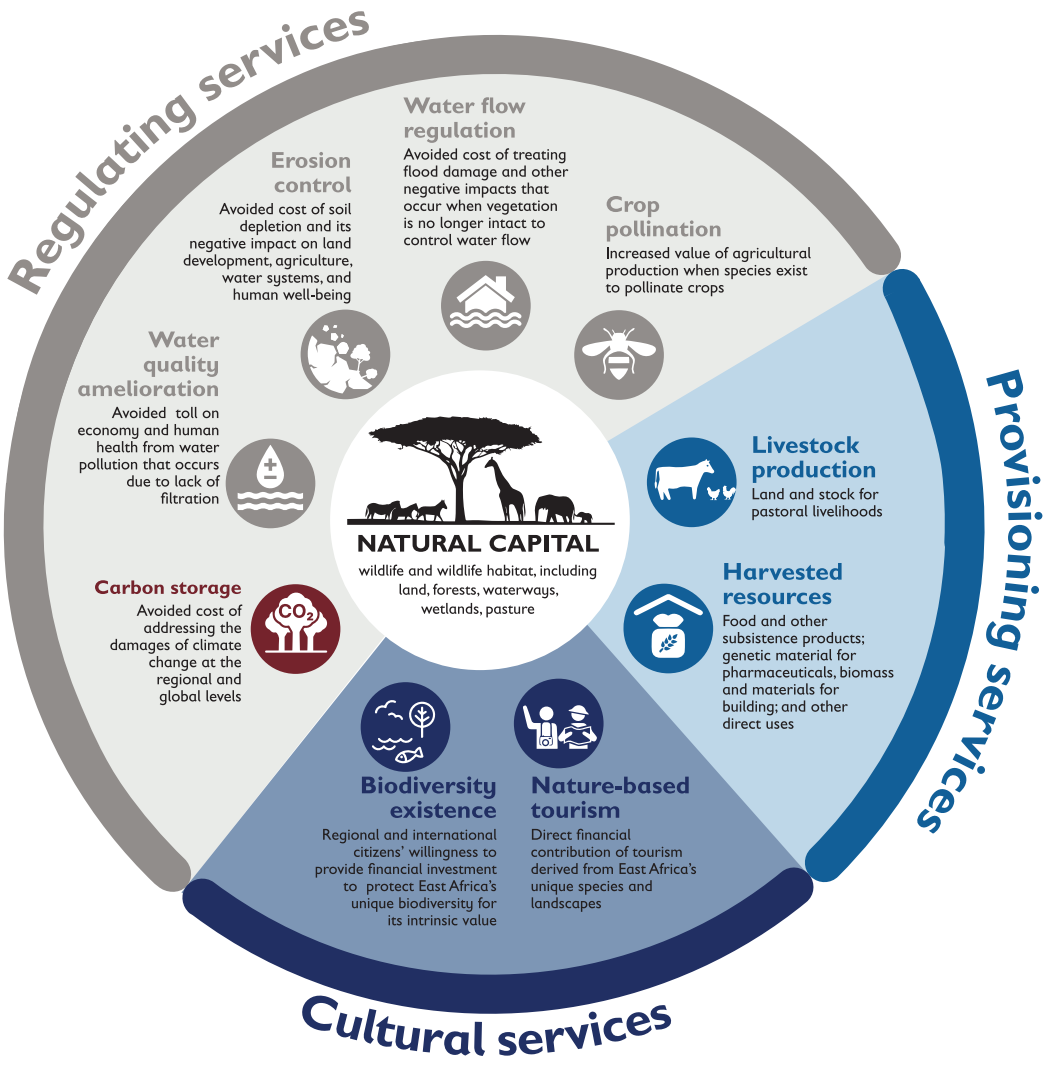


Figure 1. Overview of ecosystem services

FACTORING NATURE INTO ECONOMICS

Ecosystem services underpin the needs of all stakeholders in a landscape

Ecosystem services impact all stakeholders at the landscape level – from smallholder farmers who harvest resources to private sector businesses that rely on the steady flow of water to policymakers who rely on carbon storage to forestall the negative impacts of climate change.

Ecosystem services impact the economy and jobs

Nature-dependent sectors such as tourism, agriculture, and livestock production make substantial contributions to national Gross Domestic Products (GDPs), but the largest contribution to the economy comes from the avoided costs that result from healthy, functioning ecosystems. Ecosystems regulate water flow, reduce pollution, support wildlife, pollinate crops, and store carbon that mitigate damage from climate change. The cost of treating or replacing any of these services can place enormous burdens on economies whose government leaders did not factor natural capital into their budgets and planning.

Businesses also often ignore the value of natural capital in their financial projections – not just the resources they use on site, but the ecosystems upstream that provide water, power, and raw materials. Businesses that are starting to calculate the value of natural capital to their supply chains are better able to mitigate the risks of those resources being depleted. They must also calculate the potential cost to the government, communities, and shareholders when their business practices cause costly environmental damages. In a landmark report in 2013 by The Economics of Ecosystems and Biodiversity (TEEB) – a global initiative focused on making nature's value visible – estimated that the world's primary production and processing sectors

Tourists on an African safari to the Masai Mara and Serengeti national park to watch animals

> **$7.3 trillion**
>
> *Unpriced natural capital costs incurred by the primary production and processing sectors globally*

incur unpriced natural capital costs totaling $7.3 trillion, which equates to 13 percent of global economic output in 2009 (TEEB, 2013). These costs come from greenhouse gas emissions, water use, land use, air pollution, and waste.

Even when natural capital value is known, conservation investment lags behind

Unfortunately, conservation of wildlife and habitat is frequently seen as more cost than benefit to governments and businesses. This results in a conservation investment that is not commensurate with the extensive contributions that the wildlife economy can, and does, make in terms of employment and revenues (ALU, 2020). As an example, in 2019, the tourism sector represented on average 8 percent of the GDP in Kenya, 5 percent in Uganda, 10 percent in Rwanda and 11 percent in Tanzania. However, the budget allocations to conservation (tourism, wildlife and environment) were not commensurate, totaling 1.4 percent in Kenya, 1.7 percent in Uganda, 3.8 percent in Rwanda and one percent in Tanzania of total development expenditure (Xia, 2020).

A natural capital framework helps demonstrate the importance of conservation to economic development.

This synthesis was designed to provide leaders across all sectors with data to help inform how best to integrate natural capital into policy and financial decision making.

> "Human economic activity makes extensive use of the ecosystem services nature provides, but these barely feature in measurements of GDP. It is vital to restore nature to economic analysis and policy before the damage to the natural world – and thus to everybody's standard of living – becomes irreparable."
>
> —Award winning economist Diane Coyle, UK

Wildebeests in heavy rainfall, Maasai Mara

PHOTO: DR AJAY KUMAR SINGH

II. TAKING A LANDSCAPE-LEVEL APPROACH TO VALUING AND PROTECTING NATURAL CAPITAL

East Africa's natural capital – its iconic wildlife, forests, grasslands, and waterways – spans across national boundaries, industry sectors, and habitat types, delivering ecosystem services on which many stakeholder groups are mutually dependent. That's why valuing and protecting East Africa's natural capital must occur not only at the site or sectoral level, but rather at the landscape level. With landscape level thinking, stakeholders can begin to view themselves as part of an interconnected system and understand how they both impact on and benefit from shared natural assets.

FIRST EVER LANDSCAPE ASSESSMENT OF NATURAL CAPITAL FILLS EVIDENCE GAP

The wildlife landscapes selected for this study are internationally-renowned as tourism destinations, and so it has been largely assumed that their primary economic value lies in tourism. However, this assumption puts the landscapes in jeopardy from a policy perspective, since the tourism economy is only a fraction of the value of the wildlife and habitat in this region.

This synthesis provides a first regional-scale assessment of a comprehensive suite of ecosystem services in four transboundary wildlife landscapes of the EAC region. These landscapes, as described in further detail on the next page, include the Great East African Plains, the

PURPOSE OF SYNTHESIS

This synthesis supports the Economics of Natural Capital in East Africa Project, an initiative of USAID and the EAC to strengthen regional efforts to address national-level problems that are exacerbating the decline in wildlife populations and habitat loss. This includes strengthening the EAC regional policy dialogue; growing the evidence base on transboundary natural resource management; and providing research, data, and economic analysis on the current and potential value of natural capital in East Africa to the EAC, Partner States, regional governments and institutions, civil society organizations, and end users.

A view of Lake Nakuru, Kenya

CREDIT: VOLODYMYR BURDIAK

Northern Savannas, the Albertine Rift Forests, and the Ruweru-Mugesera-Akagera Wetland system. (See map next page.)

The landscapes were chosen in consultation with the EAC and Partner States based on their economic and cultural importance, as well as their unique species and habitats. While these species and habitats often are a key tourism draw, their very existence is also an important indication of the overall health of ecosystems that serve millions of people living in and around these landscapes.

USAID (2021) found that the four wildlife landscapes provide $11.3 billion in economic value to the region annually. The benefits to the global community are orders of magnitude greater, with total economic values ranging from $32,000 to $56,000/ha/year on average. This difference is largely due to carbon sequestration, which helps the local and global community avoid billions of dollars in addressing the damages of climate change. Whether looking through a regional or global lens, these findings are a clear indication of the high economic value of these landscapes beyond, but certainly not excluding, their conservation importance.

Building on existing frameworks

This synthesis builds on an already evolving framework – developed by a range of partners – for gathering and applying data on the value of East Africa's natural capital in the region. Four EAC Partner States (Kenya, Rwanda, Uganda, and Tanzania) are members of the Gaborone Declaration for Sustainability in Africa (GDSA), signed by African heads of state in May 2012, which is committed to incorporating natural capital into development agendas. These Partner States have made progress in quantification and mapping of natural capital. This includes:

- Kenya developed a Biodiversity Atlas (ACC, 2015) and mapped wildlife dispersal areas and migratory corridors in southern Kenya (RoK, 2012)
- Rwanda published Natural Capital Accounts in 2019 as an important tool for tracking progress on socio-economic, environment, and natural resource indicators with assistance from the World Bank and the WAVES Global Partnership (NISR, 2019)
- In their Third National Development Plan, Uganda explicitly recognized that natural resource and climate change management are central for the realization of sustainable industrialization agenda (RoU, 2020), having mainstreamed the System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA, 2014) in response to demands for integrated environmental and economic accounts.
- Tanzania identified building capacity in natural capital accounting as a main priority, and the GDSA is providing support toward achieving the Declaration's five outcomes. The country's success in community-based forest management and Southern Agricultural Growth Corridor has been identified as project demonstration for the Gaborone Declaration (GDSA, 2021).

Aside from national governments, several international non-governmental organizations (NGOs), bilateral and multi-lateral development partners, and communities of practice are playing key roles in generating evidence on natural capital in the region. Their work is cited throughout this synthesis report.

What this synthesis adds to the dialogue

Despite the increase in ecosystem service studies in the EAC region, the data remains slightly siloed – either focusing on ecosystems (mainly forests and wetlands) or sectors (wildlife, water, and food). These studies have been undertaken at different spatial scales, i.e., local, national, and regional, using a variety of modes, such as quantification, qualification, mapping, and economic valuation (Wangai et al., 2016). This synthesis is the most comprehensive analysis to date of the complex and dynamic links between wildlife, wildlife habitats, and the economy. Due to the landscape approach, the assessment includes swaths of historic forests, grasslands, rangelands and wetlands, hence providing natural capital values in a more holistic fashion and providing all facets of ecosystem valuation, i.e., quantification, qualification, mapping, and economic valuation.

OVERVIEW OF THE FOUR LANDSCAPES

Landscapes are iconic

These four landscapes represent 60 percent of total natural capital in EAC countries and contain some of the region's most important wildlife and habitat. The EAC and Partner States were aligned on their cultural importance, particularly as a tourism draw, and their economic importance, as they provide a range of ecosystem services on which millions of people and businesses rely.

Landscapes are biodiversity rich

The global average mammal diversity at the 10 km x 10 km scale is 58 species, whereas the average for East Africa is 117. In the four landscapes included in this synthesis, the average jumps to 156 species. These landscapes largely comprise protected areas, wildlife migration corridors, and surrounding contiguous areas of primarily natural land cover with wildlife. The landscapes are also Important Bird

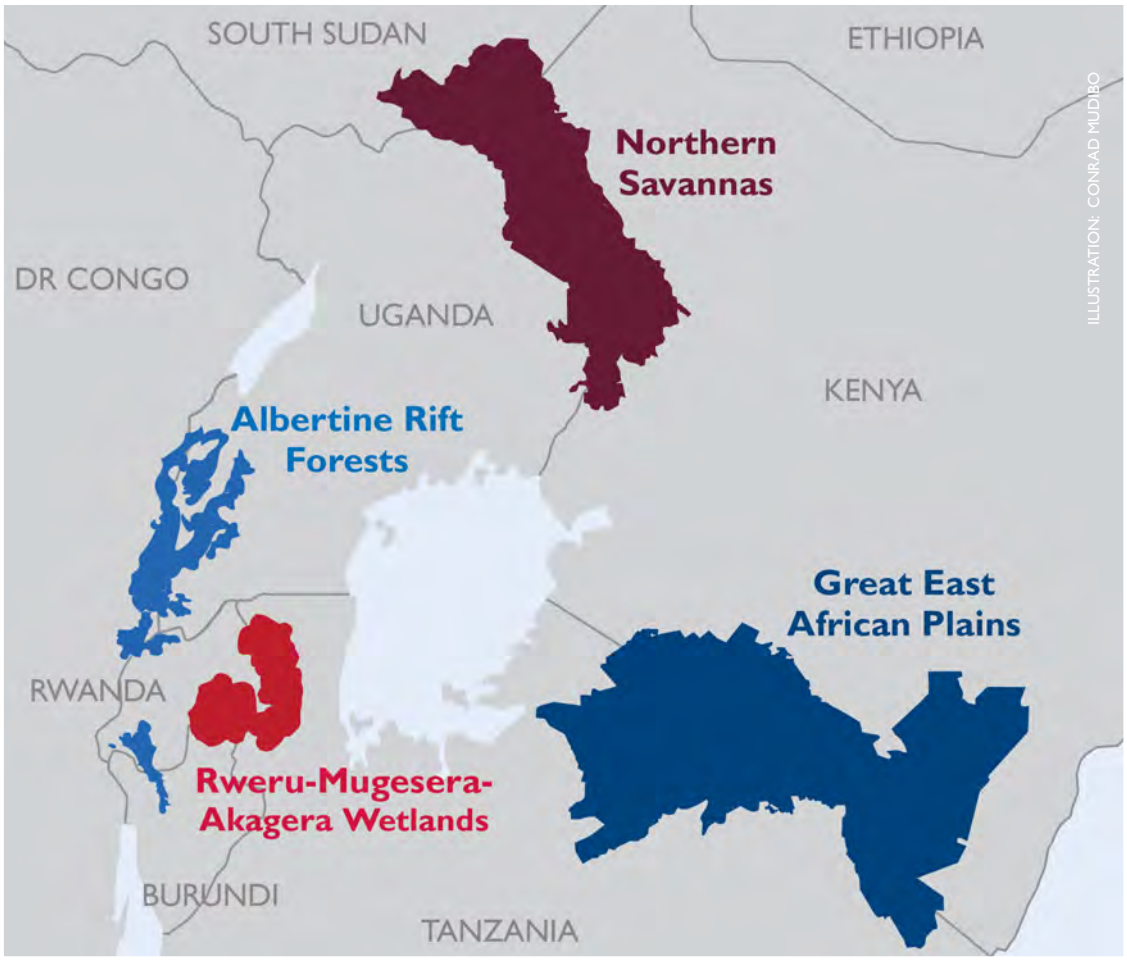


Figure 2. The four landscapes assessed

Snow capped mount Kilimanjaro, Tanzania

PHOTO: PAUL HAMPTON

Areas. The Albertine Rift Forests are also a 56,000 km^2 Endemic Bird Area straddling Burundi, the Democratic Republic of the Congo (DRC), Rwanda, Tanzania and Uganda.

IMPORTANCE OF TRANSBOUNDARY COLLABORATION

National boundaries bisect wildlife habitats, migration routes, watersheds, and dispersal areas. Changes in land cover and ecosystem function, regardless of official state borders, may have ultimate impacts on the ecological health and socioeconomic well-being for all who rely on the landscape. Hence, it is critically important for countries that share landscapes of ecological importance to coordinate in managing these areas to support the long-term viability of ecosystems and wildlife populations.

This landscape-level assessment, as well as the broader data synthesis contained in this report, will help the EAC and its Partner States work collaboratively to advance their goal of integrating natural capital accounting into policymaking. Transboundary approaches can lead to better managed shared resources, economic growth through regional integration and development, fostering community participation in management decisions, promoting peace and security, and embracing the forces of globalization (Chifamba, 2012).

Some specific opportunities for transboundary collaboration

Great East African Plains

Maintaining shared protected areas:

Kenya and Tanzania share two transboundary protected area systems, which are critical to tourism for both countries. In fact, tourism from Mara-Serengeti areas represents 5.3 percent of Tanzania's GDP and 17.8 percent of its foreign exchange earnings, as well as 30 percent of Kenya's GDP (WWF, 2019). The first shared area is the Maasai Mara Game Reserve (Kenya)/ Serengeti National Park (Tanzania) ecosystem. Each year, wildebeest, zebra, and other large herbivores migrate clockwise from the Serengeti to the Maasai Mara and back again. The migration is highly water dependent, as wildebeest require water at least every two to three days. Disruptions to water flow in the perennial transboundary Mara River and the effects of drought can have a large effect on animal populations and the size of the migration from year to year. To the southeast, Tsavo West National Park (Kenya) and Mkomazi Game Reserve (Tanzania) form a second transboundary protected area. The springs at the foot of Mount Kilimanjaro (Tanzania) feed the

Tsavo River, which flows through Tsavo West. Within this complex, the Kenya-Tanzania border also bisects the 30km^2 Lake Jipe, a Ramsar Wetland that supports both fishing and wildlife. Lake Jipe is pressured by agricultural expansion and invasive species. Kenyan and Tanzanian officials are already collaborating on improving the health of these landscapes through joint enforcement of abutting protected areas, as well as joint approaches for conserving land and water resources. Future collaborations could include public-private partnerships to support transboundary tourism, co-branding of tourism opportunities, and blended financing models.

Managing shared water resources: The Mara River flows from the Mau Escarpment in Kenya through both Maasai Mara and the Serengeti to Lake Victoria, another shared transboundary resource and the source of the Nile River. The Mara River catchment is about 13,750 km^2, of which 65 percent is in Kenya and 35 percent in Tanzania. Protection of the river and its watershed, avoiding siltation and eutrophication, is a shared responsibility. Deforestation in the upper catchments, irrigation, industrial water uses for agriculture and mining, pollution, small-scale fishing, and other uses all compete for water and affect its quality and quantity downstream and thus policy interventions require both countries.

Northern Savannas

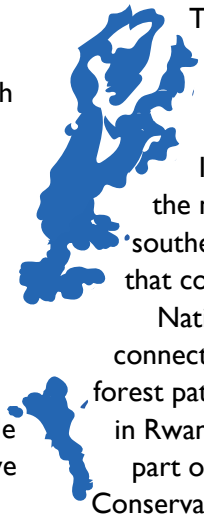
Within this landscape, South Sudan and Uganda, and Kenya and Uganda, each share a transboundary protected area system. The Nimule National Park in South Sudan is an Important Bird Area contiguous with two designated Important Bird Areas in Uganda – Mount Kei Forest Reserve and Mount Otzi Forest Reserve (Simon & Okoth, 2016). Kidepo National Park (Uganda)/KidepoGame Reserve (South Sudan) are also transboundary protected area systems. Zebras and rhinos, once abundant in this savanna, were hunted to extinction. There are perhaps 2,000 elephants, down from 80,000 recorded 50 years ago. This is why there is considerable motivation for transboundary collaboration to conserve remaining wildlife. The isolated mountain ecosystem of Mount Elgon sits on the border between Uganda and Kenya, where both countries have separately designated national parks in their respective portions of the area. The Mount Elgon Protected Area is endowed with

Several zebras drinking water from the river at the Maasai Mara in Kenya

PHOTO: GUDKOV ANDREY

exceptionally high biodiversity of global importance (Petursson et al., 2006, UWA 2018). Communities surrounding the protected area are largely small-scale farmers dependent on various products and services from the forests on the mountain. Balancing conservation and development goals requires a transboundary approach with clear rights and responsibilities to key stakeholders.

Albertine Rift Forests



The Albertine Rift Forest landscape contains some of the most diverse afromontane forests of the world, with several endemic plants, mammals, and birds (Cunningham, 1996). The only remaining connection between the national parks in northern Rwanda and southern Uganda is through corridors of forest that connect these parks to neighboring Virunga National Park in the DRC. Without this connection, these parks would become isolated forest patches. Nyungwe and Kibira National Parks in Rwanda and Burundi are contiguous and form part of the proposed Nyungwe-Kibira Transboundary Conservation Area (TFCA, IUCN ESARO, 2020), but there are no corridors that link these parks to other forested landscapes. Connectivity between protected areas like Volcanos and Queen Elizabeth National Parks within the DRC appears to


PHOTO: ZARUBA ONDREJ

Colobus monkey, Rwanda

have been vital for helping to maintain populations of large mammals in this part of the landscape. Substantial habitat loss is occurring in the DRC's Virunga National Park due to armed conflict, the expansion of cultivation and settlement, mining, and oil and gas exploration (Plumptre et al., 2016, 2017; Christensen & Arsanjani, 2020). This threatens to further reduce landscape connectivity in the region, hence the need for regional collaboration.

Rweru-Mugesera-Akagera Wetlands

This landscape is one of the largest wetland systems in the basins surrounding Lake Victoria. Large areas of papyrus swamps cover this wetland, as well as several open water lakes that are home to a wide array of birds and wildlife. Parts of the wetland system are protected in Burundi and Rwanda, and Akagera National Park is one of the largest protected wetlands in East Africa. In Rwanda, these wetlands are reportedly the second richest habitat for mammals outside of national parks (Karame et al., 2017). The landscape is within the transboundary Kagera River Basin, covering an area of 59,700 km2 with a population of over 16.5 million people whose main livelihood is agriculture. It also contributes 33.5 percent of the water inflow to Lake Victoria. This wetlands system is able to remove large quantities of the nutrients that enter as a result of human activities in catchment areas. These nutrients would otherwise reach Lake Victoria, adding to the challenges of eutrophication, hence the need for transboundary collaboration.


Lake Victoria Fishing

PHOTO: TATJANA HENDZEL

PHOTO: GUDKOV ANDREY

Colony of Bee-eaters in their burrows on a clay wall, Uganda

III. SYNTHESIS METHODOLOGY AND APPLICATION

USAID and its partners are working at multiple levels to ensure that factoring the value of natural capital into policy and development decisions becomes standard practice in East Africa. This synthesis report, as well as a range of related stakeholder engagement activities, are key to this effort. Together, they aim to:

- Strengthen the evidence base: USAID has conducted the region's first ever landscape-scale natural capital assessment in order to develop more meaningful, actionable data that can be used by multiple Partner States to integrate and improve their conservation investments. This report synthesizes that assessment with other available research and analysis on the region's natural capital, as well as on the threats and competing interests that are threatening its value. Section IV contains a high level summary of the findings.
- Encourage buy-in among key stakeholders: USAID is also using this synthesis as a convening mechanism – engaging stakeholders at every stage of planning, conducting, and validating a formal assessment of the economic and intrinsic value of the region's wildlife and wildlife habitats. Findings from this synthesis will also be packaged into a range of communication tools that help stakeholders understand, share, and adopt evidence and incorporate it into decision making.

SYNTHESIS METHODOLOGY

The assessment team carried out this study in four distinct phases: 1) landscape selection; 2) data collection; 3) ecosystem delineation and classification; and 4) ecosystem services quantification and valuation.

1. **Landscape selection.** Four broad study areas were selected on the basis of inputs from stakeholders at an inception workshop, including technical experts from the EAC, Partner States and wildlife-related NGOs.
2. **Data collection.** Once the landscapes were identified, information on the wildlife and ecosystem characteristics of the study areas, as well as on the region more generally, was collated and reviewed to understand context and to identify the nature and potential spatial geography of ecosystem services supply and demand. Where multiple data sets were available, they were carefully evaluated in order to select the most appropriate for the study. Based on data availability, the assessment was done for the situation as of 2018. The team also conducted an extensive literature review to augment this assessment, as described in Section VI. Existing global datasets were used to measure natural capital stocks and flows. The estimates presented are therefore only as robust as the underlying datasets.

Mt Elgon, Uganda, a patchwork of habitat types from rainforest to savanna grasslands

3. **Ecosystem delineation and classification.** Ecosystems were then delineated and classified at the regional scale, based on a combination of land cover, vegetation maps, and indicators of vegetation condition. The IUCN's Global Ecosystem typology was used as far as possible in grouping habitat types. The final classification comprised 72 habitat types, which includes a degraded and undegraded form of each natural habitat type where relevant. These were combined into 23 functional groups. The number of habitat types within each study area ranged from 19 in the Wetlands to 51 in the Great East African Plains. The next step was to delineate the boundaries of the wildlife landscape study areas using spatial data. This was based on largely contiguous areas of natural habitats within a biome or broadly similar ecosystem types in and around the key protected areas that had been identified. Boundary delineation was also guided by topography to some extent. Although the areas were largely defined by contiguous natural habitat, the inclusion of some areas of human habitation and agriculture was unavoidable.

4. **Ecosystem services quantification and valuation.** Ecosystem services were then quantified in physical terms where appropriate and valued in terms of US dollars per hectare per year. As far as possible, the approach involved estimating the actual use and value of each service based on the estimated capacity of the different ecosystem types to deliver these services, as well as estimated demand. The approach is spatial because values depend on context and vary in space as well as time. The landscape capacity to supply services varies with topography, climate, and ecosystem type and condition; and the human demand for services varies spatially, with population density, infrastructure, and location. The combined flow of values was used to estimate the asset value of each landscape in terms of its net present value over 30 years.

The System of Environmental Economics Accounting - Experimental Ecosystem Accounts (SEEA EEA; UN 2014), a framework that integrates economic and environmental data, was used in the assessment. This produces internationally comparable statistics on the stocks and changes in stocks of environmental assets, as they bring benefits to humanity (UN, 2021). While it is not an accounting exercise, it aligns with the building blocks of Natural Capital Accounting to provide a framework for producing Sustainable Development Goals (SDG) indicators.

As shown in Figure 1 on page 7, the synthesis quantified the following nine ecosystem services. The SEEA EA's three broadly agreed upon categories of ecosystem services was used to calculate each service:

Provisioning Services

- **Harvested resources:** The value of wild natural resources harvested from ecosystems for subsistence or small-scale agricultural production or building. This ecosystem service was calculated by mapping the stocks of wild resources based on land cover type, as well as the demand for resources based on demographic factors.

- **Livestock production:** The number of livestock supported per hectare. The value was determined by considering the direct contribution of extensive livestock production to GDP and disaggregating this value by a global geographic dataset of estimated livestock density per 10km.

Cultural services

- **Nature-based tourism:** Direct tourism contributions to national GDP. This is mapped across the landscape by mapping the density of geotagged tourism photos posted to social media.

- **Biodiversity existence:** This is measured by willingness to pay for conservation by regional and international donors based on the intrinsic value of biodiversity – i.e., knowing that it exists for human well-being and the enjoyment of future generations.

Regulating services

- **Water quality amelioration:** The avoided cost of having to remove harmful contaminants and nutrients from water supplies, because these elements have already been regulated by healthy ecosystems. This was

calculated using InVEST to compare nutrient runoff based on land cover to what it would otherwise be in a denuded landscape.

- **Erosion control:** The avoided cost of addressing soil depletion over time, due to healthy vegetation holding soil in place. This was calculated by using InVEST to model the expected degree of erosion based on land cover and comparing it to what it would be if the landscape were denuded.
- **Water flow regulation:** The avoided cost of building water infrastructure to service people who were otherwise able to obtain water for domestic use from existing natural sources. This was valued by mapping baseflow (an area's contribution to water flow based on land cover, compared to how water would flow if the landscape were denuded), demand for water, and the cost of developing infrastructure.
- **Crop pollination:** The increased agricultural output of regions that are serviced by pollinators, calculated by using a previously-developed model explaining the relationship between crop productivity and percent of land cover outside of a farm that is pollinator habitat. Previous research shows that greater levels of pollinator habitat are positively associated with higher crop productivity.
- **Carbon storage:** The assessment estimated the social cost of carbon (SCC), a metric of the expected economic damages from carbon dioxide emissions. These are typically estimated in terms of changes in GDP, a directly compatible measure for ecosystem accounting. This is an important number for thinking about impacts of climate change. It provides useful insight into distributional impacts of climate change in the region, and this evidence can be applied to national strategic incentives for green recovery decisions. This valuation relied on up-to-date information about the carbon stocks in the landscapes, as well as economic impacts of carbon contributions to climate change. SCC indicates how much intact habitats are worth to us today to avoid the damage that is projected for the future. Therefore, the SCC, as estimated in the assessment, provides an opportunity for policy makers in the EAC to incorporate the social benefits from reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions.

Preliminary validation

Due to travel restriction arising from the Coronavirus Disease 2019 (COVID-19) pandemic and the vastness of the four landscapes, researchers were not able to go into the field to ground-truth remotely acquired data by means of in-situ observations. Instead, the team relied on globally-available data and an extensive literature review, using more than 350 articles and reports. This turned up a large amount of data used to fine-tune models, while staying within the validity parameters set by the EAC technical working group.

LITERATURE REVIEW AND SYNTHESIS

After assessing the ecosystem services currently provided by the four landscapes, the team then conducted a literature review to determine what other data already existed from the many public and private sector organizations who measure biodiversity quantity, quality, diversity, and threat to existence in this region. A list of additional third party studies reviewed can be found in Section VI. These studies were critical to informing the economic valuation of natural capital in the East African region, as well as determining the threats that may impact natural capital's ability to provide the social and economic services on which people, households, and businesses depend.

Next steps

This synthesis is a living document, which has since been used to convene stakeholders in conversations through multiple channels. Stakeholders have:

- undertaken data validation
- helped determine how to leverage data and insights to make evidence-based policy and business decisions
- provided guidance on how to ensure a wider understanding of the value of the region's natural capital, the benefits of conservation, and their role in protecting the landscape

Primary data collection

Primary data has since been collected to complement information on capital required to realize service flows (knowledge, practices, etc.), and those that alter demand (e.g., institutional structures). Primary data was collected through key informant interviews and eight stakeholder workshops. Information will be incorporated in the final Synthesis Report. See section V for more details on next steps to engage stakeholders in applying findings and developing strategies to better protect natural capital.

PHOTO: KIKI DOHMEIER

IV. THE VALUE OF NATURAL CAPITAL IN PRIORITY LANDSCAPES

Great blue turaco, Rainforest, Rwanda

IV.A REGIONAL LEVEL VALUES AND INSIGHTS

This first ever landscape-level assessment of ecosystem services in East Africa offers a clear indication of the high economic value of some of the region's most iconic landscapes – value that significantly augments their conservation importance. Using conservative assumptions, the study estimates that – in addition to offering substantial habitat for wildlife populations – these ecosystems generate benefits to economic and human well-being valued at $300, $500, $700, and $1500/ha/year for the wetland, savanna, plains, and forest landscapes, respectively. Benefits to each country vary, ranging from $260/ha/year for wetlands in Rwanda to $2700/ha/year for forests in Burundi. The benefits at the global scale are orders of magnitude greater, with values ranging from $32,000 to $56,000/ha/year on average for the four landscapes.

KEY INSIGHTS

Tourism represents only 11 percent of the total economic value of these landscapes. The largest value? Regulating water, soil, and carbon.

The four landscapes prioritized for valuation are globally recognized for their biodiversity and nature-based tourism. However, their value to the economic and human well-being of the East Africa region is far greater. While revenue from tourism for 2018 was $1.2 billion, the regulating services these ecosystems provide were far more valuable at an estimated $8.18 billion per year. Regulating services include ensuring a reliable and steady flow of water to businesses and communities; filtering out pollutants to keep water clean; preventing soil erosion; and pollinating crops.

A lack of steady access to water would negatively affect livelihoods and industries that include rainfed agriculture, pastoralism, wildlife tourism, honey and charcoal production, and water-dependent private sector enterprises, such as irrigation agriculture, fishing, hydropower generation, and mining. Projections under a business as usual scenario show a potential decline in water availability by 21.2 percent by 2050 – increasing water stress and resulting in freshwater systems becoming more polluted and eutrophic. This projection represents a loss in baseflow of 3,156 million m^3 relative to the current landscape, along with an annual replacement cost of $352 million.

Wetlands in particular play a key role in purifying water, reducing the cost of infrastructure development for water treatment in the region. For example, the Nakivubo Swamp provides ecosystem services to the Greater City of Kampala to a value of $2 million a year in terms of water purification benefits, which is an avoided cost of building a water treatment plant to provide a similar service (UNEP-WCMC, 2016).

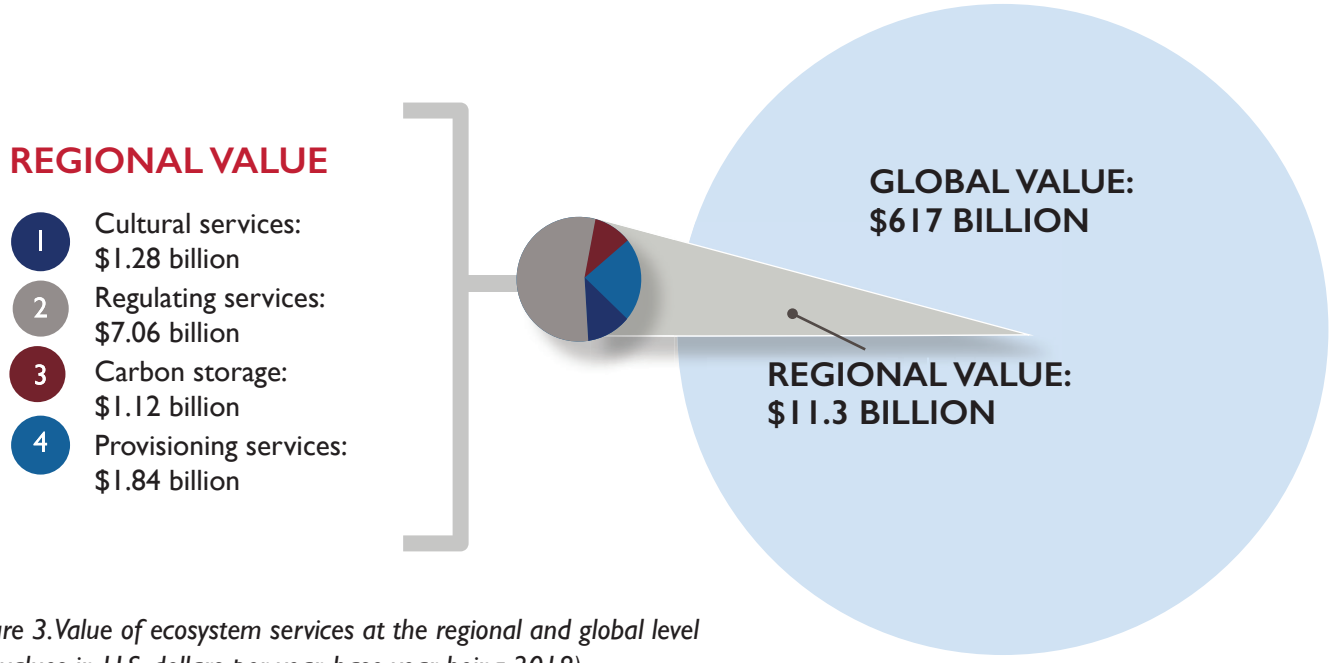


Figure 3. Value of ecosystem services at the regional and global level (all values in U.S. dollars per year, base year being 2018)

These four landscapes also regulate soil and sediment. The projected loss of forests and woody resources under a BAU scenario will lead to 166 million tons of soil and sediment being eroded – reducing soil fertility and increasing treatment costs by $204 million.

Figure 4: Findings at the landscape level

Great East African Plains

Regional annual value: $6.58 billion – More than half comes from nature's regulation of soil, water, and carbon. Another $1.2 billion comes from nature-based tourism.

Northern Savannas

Regional annual value: $3.47 billion – At $2.36 billion, water and sediment regulation are the most valuable services, underpinning livelihoods for millions. Water quality amelioration is also key to livelihoods, including fisheries around Lake Kyoga and agriculture in South Sudan.

Albertine Rift Forests

Regional annual value: $1.19 billion – Erosion control (valued at $685.5 million) and materials harvested from nature ($352.1 million) for livestock, building, sale, or energy represent the majority of value. Landscape is also a global conservation priority.

Ruweru-Mugesera-Akagera Wetlands

Regional annual value: $64.4 million – Majority of value comes from provision of natural material for food, building, and other resources. At $50.2 million, these services are ten times more valuable than nature tourism at $5.3 million.

Intact ecosystems are also critical to crop pollination. Globally, pollinator-dependent crops represent 35 percent of total crop volume with an annual market value of $235-577 billion (in 2015) worldwide. The economic contribution of pollination in East Africa as a whole has not yet been calculated, but it can be expected to be significant (Kasina, 2016). However, this synthesis offers the first comprehensive assessment of the economic contribution of four key landscapes to crop pollination – estimated at $777.2 million per year. Quantifying this value is important, since crop production is projected to contribute most to natural capital wealth in the EAC by 2050 under a business as usual scenario (Lange et al., 2018).

The landscapes also store 7.5 billion tons of carbon. How? Trees, other plants, and soils absorb and keep carbon dioxide from the atmosphere where it would otherwise contribute to climate change. The landscapes continue to accumulate carbon in plants and soils over time thereby sequestering it every year. Disturbing these systems with vegetation conversion, e.g., from land use/land cover changes, can release large amounts of carbon dioxide. Too much carbon dioxide being released into the atmosphere means too much change to our global climate, which brings negative impacts such as extreme temperature fluctuations, drought, and flooding. That's why keeping forests, wetlands, and other nature-rich ecosystems intact is so important. In fact, the study estimates that, without these landscapes, it would cost the region an additional $1.1 billion a year to address the negative impacts of climate change on social, economic, and human well-being.

Together, regulating water, soil, crop pollination, and carbon **saves the region $8.18 billion annually** - 72 percent of the total economic value of these four landscapes.

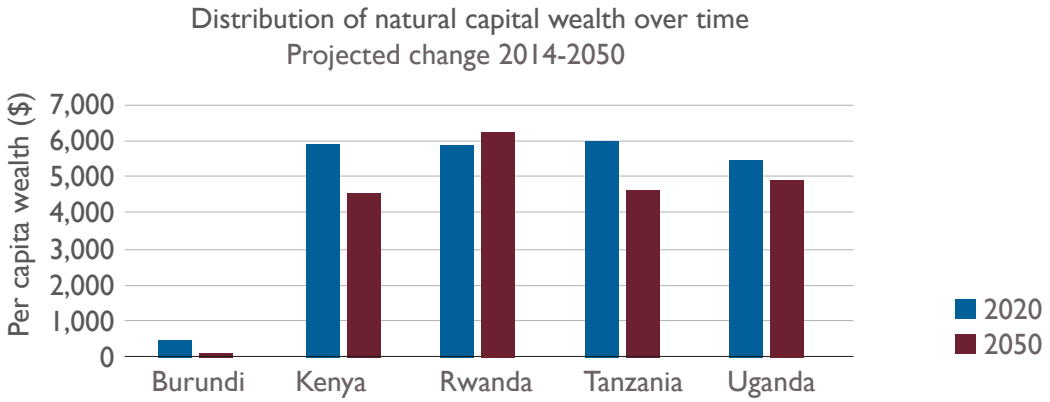


Figure 5. Projected change in natural capital as a percentage of per capita wealth for Burundi, Kenya, Rwanda, Tanzania and Uganda between 2014 and 2050 under business as usual scenario (Lange et al., 2018).

2 While regulating services represent the majority of these landscapes' value, tourism still plays an important role in the regional economy and perceived value globally.

Nature-based tourism contributed $1.2 to regional GDP in 2018, including supporting a significant number of jobs. In 2018, conservation, tourism, and related services – including hospitality, handicrafts, and travel infrastructure – provided 786,663 jobs (34,703 in Burundi, 325,034 in Kenya, 76,980 in Rwanda, 315,260 in Tanzania, and 34,686 in Uganda).

The iconic wildlife in these landscapes are also ambassadors for the region, attracting tourists from across the globe. In fact, an assessment of consumers' willingness to pay for tourism experiences and services vs. current income from this sector revealed an additional $1.5 billion in untapped revenue were the sector to adjust prices and offerings.

Tourism is also a major source of foreign exchange earnings, which are important for macroeconomic stability and debt servicing. In Kenya, for example, international tourism earnings are about 15 percent of total export earnings. Tourism is the third largest source of foreign exchange (after tea and coffee). By contrast, foreign direct investment contributes only 1.9 percent of Kenya's GDP. In Rwanda, tourism contributions constitute approximately 27 percent of export earnings and are far more significant than foreign direct investment which accounts for 3.8 percent of the country's GDP. Tourism accounts for 54 percent of foreign exchange earnings in Tanzania. Annual tourism earnings from these landscapes exceed the net bilateral aid flows in Kenya, Tanzania, and Uganda. Earnings from keeping these landscapes intact for the next 17 years would pay off the national debt of $50 billion in Kenya.

3 Keeping landscapes intact is key to the sustainability of pastoral and agricultural livelihoods.

Provisioning services, including livestock production and harvesting, also contribute to the national economies. For example, in Kenya, annual charcoal production is valued at $1.6 billion, and the honey industry employs 91,000 people directly and supports livelihoods of 547,440 people (African Leadership University School of Wildlife Conservation, 2020). Livestock are culturally and economically important to pastoral communities, who use the vast landscapes for grazing, while providing space for wildlife through community-based natural resource management (CBNRM). CBNRM areas on the Kenyan portion of the Great East African Plains landscape provided direct employment to 1,074 rangers, supported 269,187 households, and made a direct monetary contribution of over $4.4 million to the Maasai Mara communities in 2016 (KWCA, 2016).

When combined with tourism, livestock production and resource harvesting in these four landscapes make a significant contribution to GDP. In 2018, this contribution was valued at 3.8 percent for Burundi, 3 percent for Kenya, 4 percent for Rwanda, 9 percent for South Sudan, 7 percent for Tanzania, and 9 percent for Uganda. In Kenya, this value was $2.9 billion accounting for 40 percent of its forex reserve.

4 Natural capital is declining as a percentage of the region's total wealth.

While many studies focus on contribution to annual GDP of the various types of capital – whether produced, human, or natural – natural capital is a critical barometer of a nation's ability to sustain social and economic well-

Elephants, Kenya

CREDIT: JULIAN HACKER, PIXABAY

being over the long term. This synthesis shows that, under a business as usual scenario, natural capital will continue to decline as a percentage of national wealth (except in Rwanda and Uganda), leaving these countries unable to sustain nature-dependent businesses, provide food security and clean water, and remain resilient to climate change and extreme weather events like flooding.

While an increase in other forms of capital, including human and produced, holds benefits for any given country's economic well-being, the loss of natural capital in certain landscapes – such as those chosen for this assessment – is particularly problematic. That is because these wildlife- and habitat-rich landscapes are providing ecosystem services on which large populations in downstream rural – and increasingly urban – areas rely. The loss of regulating services in these landscapes will significantly impact the health, quality of life, and socio-economic development of this region as a whole.

5 Global value is exponentially greater, offering potential sources of revenue to fund regional development.

The carbon stored by these ecosystems provides the global community an estimated $600 billion per year in value. This value is based on the avoided costs of mitigating climate change damages that would result if the landscapes' capacity to capture carbon from the atmosphere declines and the 7.5 billion tons of carbon stored were released into the atmosphere. An alternative way to value carbon storage is using its value in markets that have developed as a result of government and private efforts to "neutralize" carbon emissions. Some studies calculate both values. In this study, the social cost of carbon was preferred, because the marginal price of carbon in markets is not realistic at scale. However, policymakers should consider carbon markets as one possible avenue for East Africa to pursue for potential funding to augment community earnings, support conservation and development in the region.

Waterfalls in rural Burundi

PHOTO: NATHANAEL BOARER

MAIN THREATS AND POLICY PRIORITIES

The next four sections provide top threats and recommended policy priorities for each landscape. What follows are those that can best be addressed at a regional and/or transboundary level.

Threat: Over-extraction of resources

Over-extraction of resources is a threat across all four landscapes – from fuelwood harvesting that drives forest and woodland degradation to bushmeat hunting that reduces wildlife populations to papyrus harvesting that degrades wetlands. Increase in urban population growth, estimated at 5.7 to 6.6 percent, is a key driver of these threats, particularly bushmeat hunting. The current price of bushmeat in western Tanzania is between $0.85 and $1.0 per kg, which is three to five times cheaper than beef ($2.70 to $4.70 per kg). Affordability and accessibility of bushmeat will increase demand and therefore offtake of wild species, undermining the broader general wildlife populations and increasing risks of novel zoonotic disease transmission. Recent studies have shown annual offtake of 97,796–140,615 wildebeests per year (6–10 percent of 2015 population) in the Serengeti Ecosystem (Rentsch & Packer, 2015). Around the Nyungwe National Park in Rwanda, black fronted duiker is sold at $25 and bush pig at $31 at the local market, while the yellow backed duiker is rarely sold due to local extirpation from poaching (Imanishimwe et al., 2019). Trees collected in the forest are mainly used for timber and sold between $1.2 and $3 per tree, depending on size and species.

Recommended policy focus: Countries must work at the transboundary level to create sustainable livelihood options tied to conservation and improve CBNRM. Although hunting for meat and other animal products has potential in the wildlife economy, it may not be sustainable in the region based on current land tenure and demand for bushmeat, aside being illegal in some countries.

Giraffes in Serengeti National Park, Tanzania

PHOTO: MAREK POPLAWSKI

Threat: Land use conversion and degradation

Land uses that convert natural vegetation are leading to land cover changes, increasing erosion and sedimentation, and reducing water flowing through the environment. Such land uses include change in land tenure types, cropping of grasslands, and forest degradation. Land tenure changes from communal to individual is leading to habitat fragmentation, compounded by fencing. Higher stocking in the rangelands is likely to lead to overgrazing, increased human-wildlife conflict and lower tolerance for wildlife. This situation is likely to worsen in the future, with livestock numbers projected to increase by 65 percent (Kenya), 93 percent (Tanzania), and 224 percent (Uganda) by 2050 under a business as usual scenario. The likely outcomes are extirpation of iconic species (e.g., gorilla) and iconic migrations (e.g., wildebeest) due to habitat shrinkage and elimination of connectivity.

Recommended policy focus: Pursuing strategies at a transboundary, landscape level will be crucial. Establishing and promoting cross-border CBNRM offers the most scalable avenue to ensure wildlife habitats are secured, dispersal areas and migration corridors are established, wildlife are afforded protection, and inter-community conflicts are reduced. CBNRM linked to PES is considered a priority avenue to securing natural capital and building the regional economy. In Tanzania, for example, the Tanzania Forest Conservation Group has chosen community-based forest management, a specific type of participatory forest management, as the natural model for implementing REDD+ (Dutschke, 2008). Tapping into global carbon markets, as well as willingness to pay by international donors and development partners, are also viable options. PES schemes, such as the Chyulu Hills REDD+ project in southern Kenya, have demonstrated that PES can provide returns at scale from conservation of natural habitats (Damania et al., 2019). In Tanzania, Carbon Tanzania's REDD+ projects had, by 2018, protected 270,000 ha of dryland forest, incorporating over 8.2 million trees. By keeping 1,536,700 trees in the ground, the equivalent of 95 million paperback books, an additional 291,000 tons of carbon dioxide was prevented from entering the atmosphere, equivalent to 159,590 return flights from London to New York. Of the carbon credit accrued, over $300,000 was paid to forest communities (Carbontanzania, 2021).

Triple threat of COVID-19, climate, and conflict

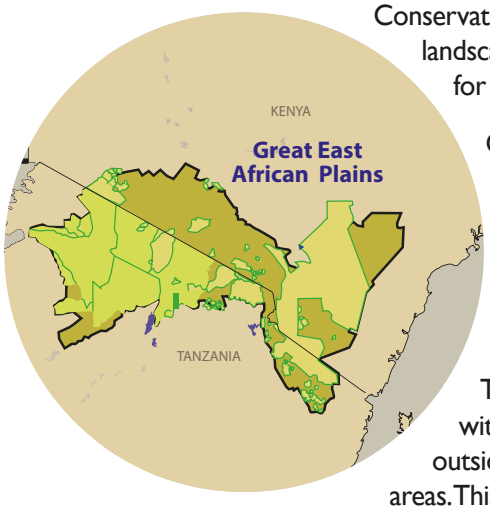
All of the threats to these landscapes, as detailed throughout Section IV, will be exacerbated by climate change – with increased temperatures, flooding, and drought further degrading habitat suitability and connectivity, as well as increasing competition for resources. The COVID-19 pandemic has now put resources and people under further strain, reducing nature-based tourism along with the financial viability of protected areas. As the region attempts to recover, as well as prosper in the longer term, wildlife and habitat loss will continue to reduce livelihood and food security; shift wealth distribution; and alter power structures and group identities – all leading to an increase in conflict. As policymakers create COVID-19 recovery plans, they should address the interconnected threats of (1) health pandemics both current and future, (2) ongoing damages from climate change, and (3) rising conflict due to the growing scarcity of resources.

PHOTO: HORDYNSKI PHOTOGRAPHY

IV.B GREAT EAST AFRICAN PLAINS

NATURE

The Great East African Plains support some of the highest density and most diverse large herbivores on earth, as well as some of Africa's most famous protected areas – drawing more than one million visitors each year to Kenya and Tanzania. Conservationists value this landscape as a global hotspot for vertebrate endemism.



Compared to much of the East African region, this landscape holds exceptional populations of wildlife within a contiguous area of natural habitat. This wildlife is found within and, importantly, outside of formally protected areas. This landscape also hosts world-famous mammalian migrations: more than one million wildebeest, gazelle, and zebra cross plains and rivers in search of greener pasture each year.

Multiple large mountains produced by volcanic activity rise out of the plateaus of this region including Mount Kilimanjaro, the highest mountain in Africa at 5,895 m. The region is primarily semi-arid to arid, with vegetation ranging from the productive, mostly treeless short-grass associations of the Serengeti Plains to wooded grassland, bushland, thicket, Acacia woodland, and montane forests.

LANDSCAPE AT-A-GLANCE

- **Total population:** just under 9 million (more than 2/3 in Tanzania)
- **Population density:** Low (~69 people/ km^2)
- **Rural population within landscape:** Kenya: 97%; Tanzania: 88%
- **Average resource use per hectare:** Low (due to low population density, high percentage of land under protection, and coverage by habitats with moderate to low stocks of most natural resources)
- **Land area:** Kenya—68,720 km^2 (11.8% of total land); Tanzania—60,913 km^2 (6.4% of total land)
- **Protected areas:** Kenya—23,074 km^2; Tanzania—26,657 km^2
- **Area under CBNRM:** Kenya—11,000 km^2; Tanzania—2,293 km^2
- **Transboundary protected areas:** Mara-Serengeti and Tsavo-Mkomazi with joint elephant census
- **Transboundary river basins:** Ewaso Ng'iro River, Mara River, Pangani River

NATURE'S BENEFICIARIES

Nature underpins the livelihoods and well-being of all of the nearly nine million people living in this landscape. Following is a look at key stakeholder groups.

Pastoralists, agro-pastoralists, smallholder farmers

Livestock – mainly cattle, with some sheep and goats – is the most important source of livelihood and food security for communities in this landscape. There are 2.3 million livestock units contributing $247.8 million to Kenya's GDP and $309.6 million to Tanzania's GDP. Specialized pastoralism has been on the decline for some decades, with the majority of households diversifying toward agro-pastoralism or non-farm activities (Homewood, Kristjanson & Trench, 2009).

Smallholder farming is also key to the livelihoods of a significant portion of the population. The main cash crops are cotton, sweet potato, and rice, which produce relatively low yields compared to other study regions. Maize and cassava are grown by most households for their own consumption.

Tourism sector

The total direct contribution to GDP of nature-based tourism was estimated at more than $1.2 billion in 2018, the highest of the four study areas. Nature-based tourism also generated an estimated $1.5 billion in net benefits (consumer surplus) through ancillary goods and services, such as transportation, restaurants, handicrafts, and other provisions for international tourists.

Note: the ecotourism industry has been significantly disrupted in 2020-21 due to the COVID-19 pandemic. Nature-based tourism has declined significantly due to associated travel restrictions and fears, and recovery will be threatened by wildlife losses during the pandemic and current and future climate change.

Other private sectors

There are several other downstream private sector industries that rely on access to natural capital. These include agriculture and mining in the Mara River Basin, fishing in Lake Victoria, and commercial and traditional irrigation facilities, hydro-power, and mining in the Pangani River Basin (PRB).

NATURE'S GUARDIANS

There are a range of stakeholders at the local, national, regional, and global levels, who influence stewardship or directly steward natural capital in this landscape.

Community conservancies

In Kenya, 76 community conservancies provide 11,000 km^2 of space to wildlife. These CBNRM areas provide direct employment to more than 1,000 rangers and have made a direct monetary contribution of more than $4.4 million to the Maasai Mara communities (KWCA, 2016).

In Tanzania, three wildlife management areas (WMA) totaling 2,293 km^2 include: (1) Ikona WMA (242 km^2) comprising five villages to the northwest of Serengeti National Park; (2) Makao WMA (780 km^2) comprising seven villages in the south-western Serengeti Ecosystem; and (3) Enduimet WMA (1282 km^2) comprising nine villages in West Kilimanjaro Basin. The WMAs expand private sector access to conserved areas with potentially more diverse economic opportunities.

National and regional policymakers

The EAC and its Partner States, including Kenya and Tanzania, play a key role in stewarding the region's natural capital. The national governments in Kenya and Tanzania oversee protected area management, employing rangers and other natural resource managers, as well as policies that govern land use and development.

International development partners and NGOs

A range of bilateral, multilateral, and non-governmental organizations are working in this region to value and protect natural capital (see page 10 for more on leaders in this arena).

PHOTO: DELPHIN KING, LAIKIPIA WILDLIFE FORUM

Greening school, Kenya

NATURAL CAPITAL VALUE

This is an overview of the estimated value of each ecosystem service, as well as key insights to guide stakeholders toward improving protection of the natural capital that provides these services. The full assessment contains further details and analysis. **Total estimated value**: $508/ha/yr on average to East Africa; more than $31,600/ha/yr globally.

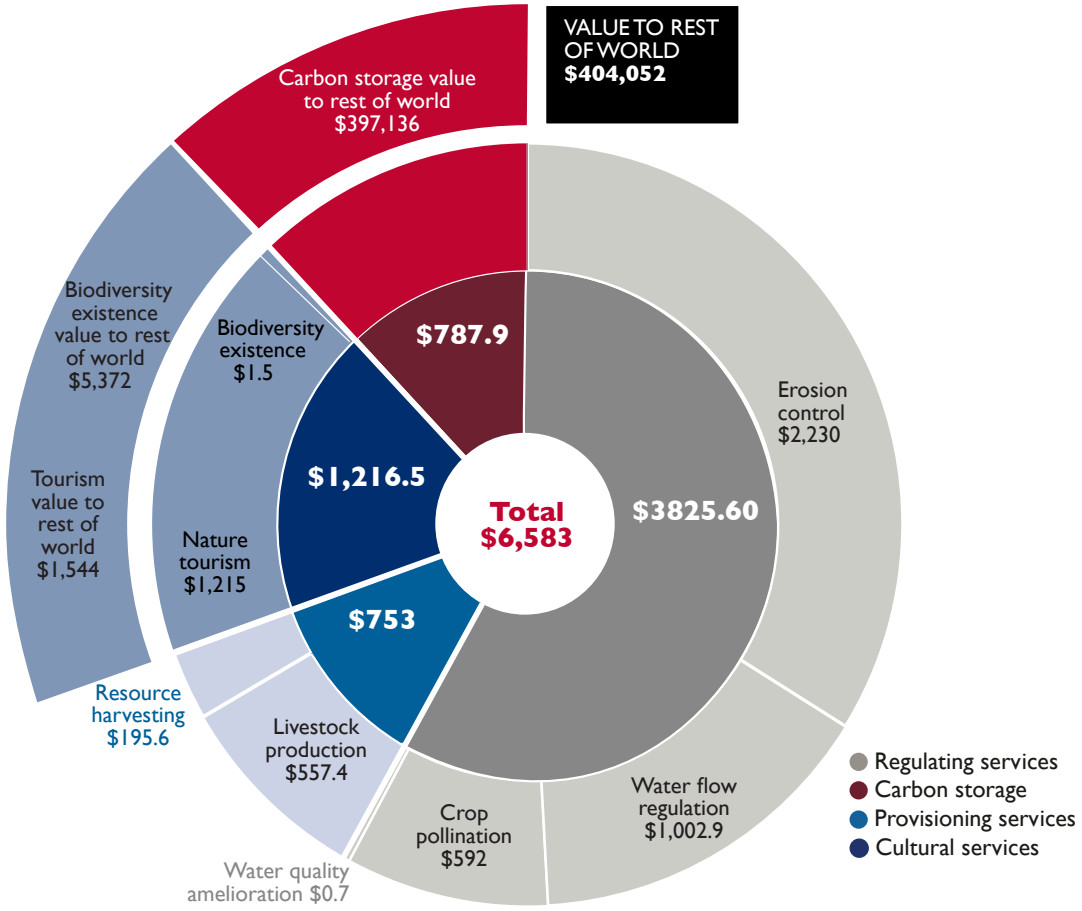


Figure 6. U.S. dollar value of ecosystem services in millions per year in Great East African Plains

REGULATING SERVICES

Water flow regulation: $1B/yr *(through infiltration and storage of 9 million m³ of rainwater)*

Water quality amelioration: $700,000/yr *(in avoided costs from reduction of phosphorous loadings by 853-4,855 tons/year within catchment areas of Lake Victoria)*

Erosion control: $2.2B/yr *(through retention of ~1.8 billion metric tons of sediment per year, which would otherwise end up in lakes, reservoirs, estuaries, and coastal environments)*

Crop pollination: $592M/yr *(in increased crop production)*

CARBON STORAGE

Regional value: $788M/yr *(in avoided costs due to storage of an estimated 4.6 billion tons of carbon – ~$290 million/yr in Kenya and ~$500 million/yr in Tanzania)*

Value to rest of world: $397B/yr *(in avoided costs from storage of same stocks)*

PROVISIONING SERVICES

Livestock production: $557.4M/yr *(in contribution to GDP)*

Harvested resources: $195.6M/yr *(based on 406,000 liters of honey harvested; honey industry also employs 91,000 people directly and supports livelihoods of 547,440 people in Kenya [ALU, 2020]).*

CULTURAL SERVICES

Nature-based tourism: $1.21B/yr *(represents 30% of total national tourism value in Kenya and 41% of total in Tanzania)*

Biodiversity existence: $1.5M/yr to regional community *(5.37B to rest of world)*

1 Water regulation and carbon storage dwarf all other ecosystem services in value

Although the Great East African Plains are renowned for tourism, the regulating services provided by this landscape far outweigh tourism in economic value. In fact, keeping the wildlife habitats in their current natural condition generates cost savings for the region that could be worth approximately $4.02 billion per year, largely through regulation of hydrological processes and atmospheric carbon. Millions of people rely on the flow of water for both household consumption and livelihoods based on agriculture, pastoralism, tourism, hydro-power, and mining.

2 Global value of carbon storage is two times the entire region's GDP

While carbon storage value to the region is approximately $788 million per year, avoided costs of climate damage at the global level are estimated at $400 billion per year – twice the 2018 GDP output of the East African region. That is why one of our top recommendations for policymakers is to consider tapping into global mechanisms to generate revenue for conservation of the East Africa region – whether large international conservation donors or carbon markets.

3 Tourism has a significant impact on jobs

As tourism is a primary source of jobs in the formal sector, investing in conservation of internationally recognized wildlife and habitats is critical to regional jobs and household income. Protected areas accounted for 21percent of Tanzania's and 11 percent of Kenya's total tourism

value in 2018, providing 638,568 jobs across the landscape (323,568 in Kenya and 315,000 in Tanzania). In addition, community conservancies on the Kenyan portion of the landscape provided direct employment to 1,074 rangers, supported 269,187 households, and made direct monetary contributions of $4.4 million to the Maasai Mara communities in 2016 (KWCA, 2016).

4 Impact on GDP from wildlife and habitat loss goes well beyond tourism

The majority of livelihoods in this landscape depend on ecosystem services. For example, livestock production, which is dependent on healthy grasslands, contributes approximately $248 million per year to Kenya's GDP and $310 million per year to Tanzania's GDP. The Mara River Basin contributes $5-7 million per year to Kenya and Tanzania GDPs based on sectors that all depend on ecosystem regulation of water, soil, and nutrients. These include agriculture, livestock, tourism, mining, and fisheries (WWF, 2019).

5 The real value lies in avoided costs

The largest value of healthy ecosystems lies not in what is produced and sold, but in those services the government does not have to pay for because they're covered by nature. Those benefits may not be immediately or even overtly visible to the average person, but the cost of not protecting nature today will be acutely felt by communities in the years to come.

THE COST OF INACTION

PROJECTED OUTCOMES BY 2050 IN A BUSINESS AS USUAL SCENARIO

TOP THREATS

1. Land conversion
2. Over-extraction of natural resources
3. *Impacts from climate change that will exacerbate threats*
   Drought, flooding, increased temperatures

STRESSES ON NATURAL ENVIRONMENT

4. Changes to vegetation and soil cover
5. Changes to habitat type and connectivity
6. Changes in fresh water quality, quantity, and flow
7. Changes in animal behavior

1 Land conversion

Demographic and livelihood shifts will drive population growth at 3.5 percent annually. Without intervention, this will lead to land conversion and degradation from increased demand for livestock, charcoal, and fuelwood; greater urbanization and infrastructure development; agricultural expansion; and land subdivision and fencing. Already one percent of the wildlife landscape is being lost annually to the expansion of cultivated area. Livestock biomass is projected to increase up to 65 percent on the Kenyan side and 93 percent in Tanzania by 2050.

2 Over-extraction of natural resources

Population growth will also lead to greater extraction of resources. A 65 percent increase in demand for biomass energy and woody resources is projected, along with a 58 percent increase in demand for bushmeat. (Wildebeest in Serengeti already experience an annual offtake of 98,000–140,000 – 6-10 percent of the 2015 population. (Rentsch & Packer, 2015).

3 Drought, flooding, increased temperatures

The impacts of climate change will vary markedly across the landscape. Lower precipitation and higher temperatures are predicted to cause substantial contraction of areas with suitable climatic conditions for most key charismatic wildlife species, including lion, elephant, and wildebeest. Increased rainfall in some areas and disappearing vegetation will also increase erosion, with implications for soil retention and fertility and water retention and quality.

4 Changes to vegetation and soil cover

The conversion of natural vegetation cover to cropland and its denudation from overgrazing, as well as the ongoing extraction of woody biomass, will decrease the amount of stored carbon and increase the rate of soil loss (and loss of soil fertility). Reduced vegetation will also reduce water penetration and storage, affecting downstream water regulation and flow.

5 Changes to habitat type and connectivity

Habitats for key species will be lost and connectivity disrupted, which will impact species, dispersals, migration and ability to adapt to climate change. An additional 2.4 million ha of habitat is projected to be converted to agriculture, fenced, or overgrazed by 2050. That would be a loss of twice the habitat currently available under CBNRM approaches.

6 Changes in fresh water quality, quantity, and flow

Water quality will be increasingly compromised by the conversion of natural habitats to cropland, which will substantially increase nutrient loads entering water systems. This will result in eutrophication of rivers, wetlands, and lakes, reducing the value of those habitats.

7 Changes in animal behavior

Recent data suggests imminent collapse of four of the five contemporary migrations (Ogutu, 2019). While wildlife populations may remain more stable in protected areas in the short term, protected areas could increasingly become isolated sanctuaries in a sea of agriculture, with little landscape or genetic connectivity between them.

This synthesis assessed the current (2018) threats to wildlife and wildlife habitat and their projected impact by 2050 under a business as usual scenario. Note that projections consider climate change and assume full recovery from the current impacts of COVID-19.

IMPACT ON ECOSYSTEM SERVICES BY 2050	IMPACT ON ECONOMIC AND HUMAN WELL-BEING
8 Reduction in value of cultural services	12 Negative impact on livelihoods
9 Increased cost due to loss of regulating capacity	13 Reduction in food security
10 Increased cost due to loss of carbon storage capacity	14 Water scarcity
11 Reduction in value of provisioning services	15 Negative health impacts

8 Tourism revenue: -13.3 percent
Annual losses – Kenya: $76 million; Tanzania: $85 million.

Existence value: -21.4%
Expected decline in willingness to pay: $1.5 million per year to $1.2 million per year by 2050.

9 Erosion control capacity: -9.2 percent
An additional 166 million tons of sediment entering rivers and waterbodies would amount to an annual $204 million increase in treatment costs.

Water flow regulation capacity: -35.1percent
Reduced capacity to regulate water flow will impact both households and businesses, with annual mitigation costs rising by $352 million.

Water quality: -33.1 percent
Increase in phosphorus production, leading to an annual replacement treatment cost of $558,000.

10 Carbon storage: -5.3 percent
Reduced capacity to store carbon will increase annual mitigation costs of climate damage by $747.6 million regionally and 3.7 billion globally

11 Follow up studies can determine the economic impact on provisioning services. Livestock production is projected to increase, while crop pollination and resources available for harvesting are projected to decline.

This assessment valued the cost of inaction associated with the potential loss of nine valuable ecosystem services. Further study is recommended to gauge the broader cost to the economy, jobs, and human well-being under a business as usual scenario. A few initial projections:

12 Negative impact on livelihoods
Negatively affected livelihoods and industries will include rainfed agriculture, pastoralism, wildlife tourism, charcoal production, water-dependent private sector enterprises such as the flower industry, irrigation agriculture, and freshwater fishing. Annual job losses from nature-based tourism are predicted at 66,427 in Kenya and 31,430 in Tanzania. Follow up studies will estimate the monetary cost to jobs and GDP across all sectors.

13 Reduction in food security for projected 14 million people

14 Reduction in Water Security
Water scarcity for 11.9 million people in the Pangani River Basin (PRB) and 2.1 million people in the Mara River Basin (MRB)

- *PRB in Tanzania will lose capacity to generate 95 megawatt (MW) hydropower (6 percent of national capacity) and 76,000 ha of irrigation (18 percent of irrigated area). Currently, 75 percent of the population is already under water stress (URT, 2020).*
- *There will be an est. 8,800 percent increase (2,620 MCM) in water demand for the MRB (Metobwa et al., 2018).*

15 Negative health impacts
Increase in zoonotic disease from compromised wildlife; public health burden from rising pollution and bushmeat consumption; increase in violence due to human-wildlife conflict.

POLICY CONSIDERATIONS

Creating solutions for protecting natural capital will take all stakeholders working together across sectors and national boundaries. The team is currently engaging an array of stakeholders in a dialogue about policy priorities and in the development of a transboundary action plan.

Top priority for this landscape: Slowing and reversing land cover change by focusing on sustainable land use strategies

As shown on the previous page, current status and future trends predict increasing degradation of grasslands, reduction of forests, compaction of soils, and other changes to land cover that – if allowed to continue – will negatively impact all stakeholders. If current management conditions and priorities persist, those who live within the landscape should anticipate less provisional resources, lower soil fertility, and reduced tourism income. People and businesses downstream will receive less water, be impacted by lower water quality, and face other disruptions to their livelihoods and preferred private sector value chains. National governments will lose a major source of foreign exchange earnings from the decline in tourism. The global community will not only lose some of the world's most iconic species, protected areas, and natural wonders, but will also experience the costly effects of increased vulnerability to climate change's impacts.

While the needs of these stakeholder groups are different, the call to action is the same: stop or reverse the trend of land cover change through ensuring appropriate land uses; make management decisions with water resources and climate change in mind; and make policy decisions that support these priorities and actions over the long term. This synthesis suggests the following potential strategies for priority consideration.

1 Tap into this landscape's large economic value to the global community

The global community has a vested interest in minimizing land cover change that releases carbon dioxide into the environment. The Great East African Plains currently provides $400 billion per year in globally avoided costs of adapting to or recovering from climate change impacts. Tapping into this community's willingness to pay for conservation should be a priority strategy. Some investment may come from international donors, but the biggest potential lies in the world's burgeoning carbon markets. However, challenges lie with designing measures that harness sufficient funds from the global community, effectively incentivize conservation among frontline communities, equitably distribute benefits among community-level stakeholders, and accurately verify carbon storage outcomes. Success will depend on engaging multiple stakeholder groups, from policymakers to economists and the private sector to community-based natural resource managers. Transboundary and regional coordination on PES initiatives like REDD+ will be critical to avoid any time-consuming competition for resources. Support from bilateral and multi-lateral institutions will also be key, including the Program on Climate Change Adaptation and Mitigation in Eastern and Southern Africa (implemented through COMESA, EAC, and SADC).

2 Implement other PES schemes that capitalize on and preserve regulating schemes

Some of the highest values this landscape provides are controlling soil erosion, reducing sediment pollution, and regulating the flow of water, particularly during extreme weather events. At the watershed level, users both upstream and downstream are mutually dependent on these regulating services, and strategies like water funds can be used to incentivize both groups to protect their shared natural capital. In this scenario, downstream users, such as private industries, hydropower initiatives, the agricultural sector, and municipalities would fund activities to keep upstream areas in good condition, thus maintaining water access for all.

3 Focus on local, national, and transboundary policies that limit land use change

Conversion of pastureland to agriculture and the erection of fences are key threats to wildlife populations, dispersals and migrations. With the right policies in place, well supported, and enforced, community-based natural resource managers are well positioned to reduce land use changes that disrupt or exclude wildlife and reduce viability of land to support diverse livelihoods over the long term. This includes restricting the amount of grasslands that are converted for agriculture, including subdivision and fencing, that change land cover patterns required for well-functioning ecosystems. Article 3.3.4(iv) of the Wildlife Policy of Tanzania (1998) supports such a strategy by

stating that "encouraging rural communities to establish Wildlife Management Areas in such areas of critical wildlife habitat, with the aim of ensuring that wildlife can compete with other forms of land use that may jeopardise wildlife populations and movements" (URT, 1998). Kenya's Wildlife Policy (RoK, 2020) also recognizes and promotes wildlife as a land use option in private and community lands.

4 Invest in tourism models that optimize both revenue and conservation

While the establishment and promotion of community conservancies offer the most scalable avenue to securing wildlife habitats and establishing migration corridors, their contribution to the tourism industry accounts for only 1.3 percent of total earnings, suggesting considerable potential to expand into sustainable tourism. Designing activities for this market can maximize revenue while minimizing impact on wildlife and habitat. Appropriate policies would provide an enabling environment for sustainable tourism as an engine of social and economic development, income, and investment, contributing to the achievement of the UN Sustainable Development Goals. The tourism sector should also consider revenue-sharing models that directly fund activities that protect the land on which their industry relies. For example, a portion of tourism revenue could be used to support community rotational grazing schemes to reduce human-wildlife conflict and ensure more land is conserved for wildlife.

STAKEHOLDER GROUPS

Stakeholder group	Call to action	Benefits to stakeholder
Smallholder farmers	Participate in efforts to bring smallholder farmers into tourism sector in order to open new markets for their produce	Increased income, greater food security, less demand for bushmeat
Pastoralists	Engage in holistic land management plans that provide space for wildlife and enable regeneration of pasture that also bank grass for drought mitigation	Healthier livestock and more valuable, regenerative pastureland
Community conservancies	Rehabilitate degraded rangelands and create policies and best practices for preserving wildlife habitat and migration corridors	Higher wildlife biomass to attract ecotourism
Tourism sector	Adopt sustainable tourism model; allocate portion of revenue to land owners and community conservancies for improved CBNRM	Wildlife/habitat that attract tourists are protected; higher, more sustainable revenue streams; women's empowerment; sectoral linkages; regional integration
Other private sectors (agriculture, mining, fishing, hydropower, irrigation)	Participate in PES schemes (watershed protection, carbon sequestration and storage [REDD+, reforestation/afforestation], and biodiversity conservation); invest in protection of land and resources that are critical to value chain	Continuity of regulating services that provide water, filter pollutants, and reduce soil erosion – all of which are critical to avoiding loss of productivity and revenue
National policymakers	Create policies that incentivize sustainable land use (zoning, alternative livelihoods) and protect land cover; policies on sustainable tourism	Avoided costs of mitigating soil erosion, water scarcity or pollution, climate change damage
Transboundary leaders (EAC and transboundary protected area managers)	Strengthen collaborative mechanisms for co-managing protected areas and shared water catchments, as well as combating illegal killing of wildlife; create policies that tap into carbon markets through avoided nature loss and nature-based sequestrations	Avoided loss of tourist revenue, avoided costs of water treatment and replacement
International donors/ development organizations	Support regional access to, and benefits from, carbon markets, and invest in CBNRM that improves climate resilience in East Africa and globally	Advance international climate agreements and frameworks

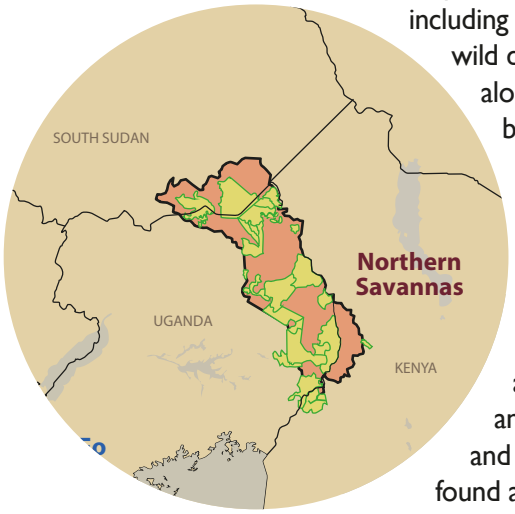
Northern giraffe, Uganda

PHOTO: COULANGES

IV.C NORTHERN SAVANNAS

NATURE

The Northern Savannas landscape is a remote wilderness with a diverse assemblage of mammal and bird species. More than 86 mammal species can be found in the northern part of the landscape, including leopard, cheetah, wild dog, and elephant, along with 500+ bird species. The landscape's grasslands are dotted with iconic tree species, such as red thorn acacias and desert dates, and sausage trees and doum palms are found along important perennial waterways.



LANDSCAPE AT-A-GLANCE

- **Total population:** 6.3 million (97% rural)
- **Population density:** Moderate (~129 people/km^2)
- **Land area:** 48,848 km^2
- **Area under protection:** Kidepo Game Reserve/Kidepo Valley National Park and Nimule National Park/Otze Forest Reserve in Uganda and South Sudan; Karamoja cluster conservation areas in Uganda and neighboring community conservancies in Kenya; and Mount Elgon National Park in Kenya and Uganda

There are a number of transboundary interests in this landscape. The Turkwel Basin encompasses both the Kenyan and Ugandan portions of the study area. It includes the Turkwel Dam, which is the third largest hydroelectric power plant in Kenya, producing 106 MW of power a year (Hirpa et al., 2018). In the Turkana region of Kenya, there are also a number of small-scale irrigation projects that depend on the Turkwel River, which would be negatively impacted by any activities in Uganda that increase sedimentation and/or decrease base flows within the Turkwel Basin. Uganda's Kidepo Valley National Park is a focal point for the relatively small wildlife tourism industry in the landscape and is the main remaining stronghold for savanna wildlife in the area. However, this status is threatened by transboundary poaching from South Sudan. Tourism could also be negatively impacted by deterioration of the security situation in South Sudan.

NATURE'S BENEFICIARIES

Nature underpins the livelihoods and well-being of all of the over 6.3 million people living in this landscape. Following is a look at key stakeholder groups.

Smallholder farmers, pastoralists, fishers, and small-scale miners

The region around Mount Elgon is predominantly agricultural, and it can usually count on bumper harvests from maize, groundnuts, cassava, and other crops. In Kenya, 5,000 people depend on the Mount Elgon forest for subsistence products, such as firewood, poles and posts, water, game meat, and medicinal plants (Ongugo et al. 2002). On the Ugandan side of the mountain, illegal hunting is commonplace, whether for food, use in circumcision ceremonies, or cash income (Jankulovska et al. 2003). Downstream, agropastoral and nomadic lifestyles drive settlement patterns, with some villages becoming heavily depopulated during the dry season. Communities in Kidepo Protected Area Cluster (KPAC) are primarily agro-pastoralist, and fishing is practiced on the shores of Lake Kyoga. Artisanal gold mining is practiced in the Karamoja Districts but limited by insecurity, lack of water, and other basic services in mining areas (Burns et al., 2013). Illegal gold mining has been recorded in protected areas around River Kidepo and Kurao.

Commercial farming

Commercial farming in this landscape is largely focused on rice, coffee, and dairy.

Tourism sector

The value of nature-based tourism in this landscape was estimated at $8.9 million in 2018. Varied landscapes, as well as the presence of unique wildlife in Uganda, are the current draw. The transboundary nature of the KPAC in Uganda and Kidepo Game Reserve in South Sudan offer an opportunity for collaboration on sustainable tourism.

NATURE'S GUARDIANS

There are a range of stakeholders at the local, national, regional, and global levels, who influence stewardship of natural capital in this landscape.

Community groups

There are a few community conservation areas in this landscape, including Karenga Community Wildlife Management Area, Amudat Community Wildlife Area, Iriri Community Wildlife Area, and Bokora Corridor Wildlife Reserve.

National and regional policymakers

National agencies that play key roles in stewarding the region's natural capital include Kenya Wildlife Service, Kenya Forest Service, Uganda Wildlife Authority, Uganda's National Forestry Authority and National Environment Management Authority, and the Wildlife Conservation Directorate of the Government of South Sudan.

International development partners and NGOs

The African Wildlife Foundation (AWF) is working in Imatong, South Sudan, and Wildlife Conservation Society is working in both South Sudan and Uganda in the Kidepo area.

PHOTO: MACIEJ CZEKAJEWSKI

Sunset at savannah plains in Tsavo East National Park, Kenya

NATURAL CAPITAL VALUE

This is an overview of the estimated value of each ecosystem service, as well as key insights to guide stakeholders toward improving protection of the natural capital that provides these services. The full assessment contains further details and analysis. **Total estimated value**: $710/ha/yr on average to East Africa; more than $31,700/ha/yr globally

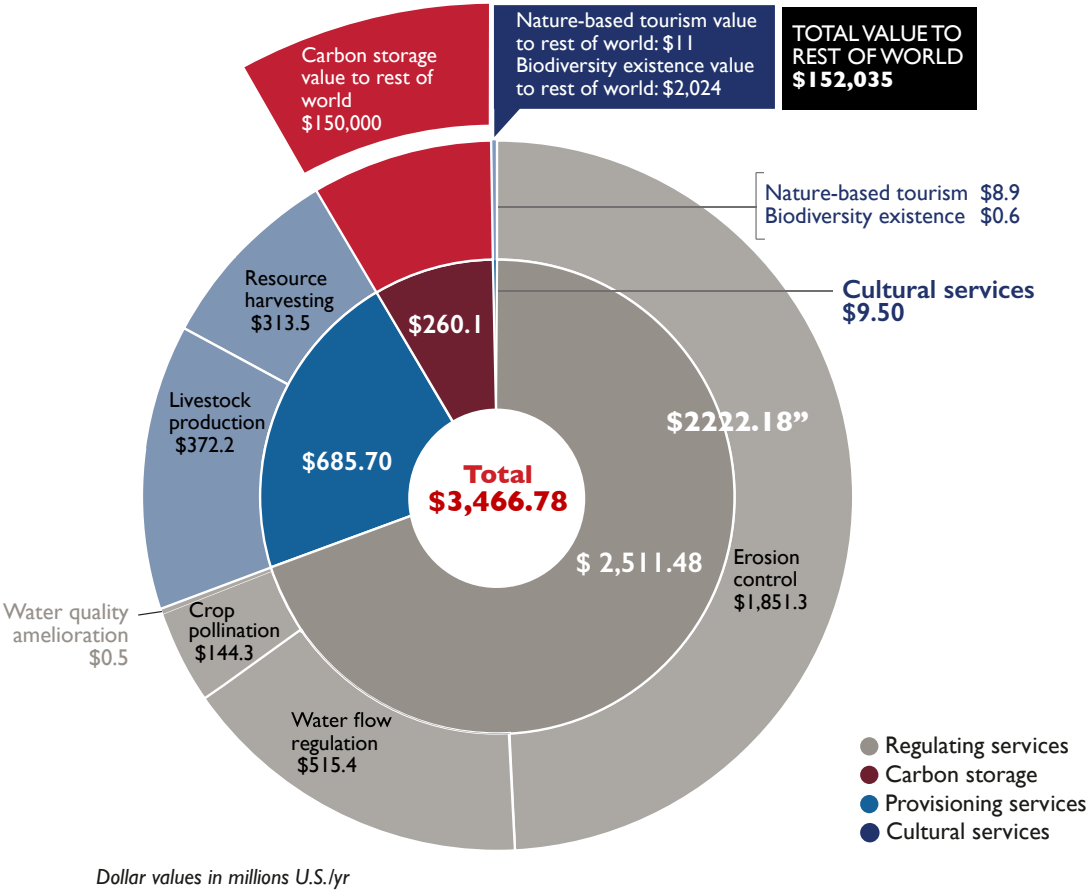


Figure 7. U.S. dollar value of ecosystem services in millions per year in Northern Savannas

REGULATING SERVICES

Water flow regulation: $515.4M/yr

Water quality amelioration: $0.5M/yr
(in avoided costs from reduction of phosphorous loadings within catchment areas of Lake Kyoga)

Erosion control: $1.85B/yr
(through retention of 1.27 billion metric tons of sediment per year – the highest retention occurring in South Sudan at 398 tons/ha/yr)

Crop pollination: $144.3M/yr
(majority of value, 67%, is in Uganda; 22% of value is in Kenya and 11% in South Sudan)

CARBON STORAGE

Regional value: $260.1M/yr *(in avoided costs due to storage of an estimated 2.2 billion tons of carbon)*
Value to rest of world: $150B/yr *(in avoided costs from storage of same stocks)*

PROVISIONING SERVICES

Livestock production: $372.2M/yr
(in contribution to GDP)

Harvested resources: $313.5M *($135.3M in Uganda; $117.9M in South Sudan; $60.3M in Kenya)*

CULTURAL SERVICES

Nature-based tourism: $8.9M/yr
(represents 6,686 jobs in Uganda; 1,466 jobs in Kenya)

Biodiversity existence: $600,000 to regional community/yr
($2.02B/yr to rest of world)

KEY INSIGHTS

Hydrological regulation and sediment retention support both livelihoods and nature.

In this landscape, hydrologically-linked ecosystem services have significant local and regional value. Livelihoods in the Mount Elgon region – whose population includes 2.9 million people on the Kenyan side and 1.8 million on the Ugandan side – are dominated by rainfed agriculture (Bonzemo, 2018; UIA, 2018). Sustainable agricultural production is dependent on water flow regulation and water quality amelioration. Natural vegetation in this landscape is estimated to contribute approximately 4.6 million m^3 of rainwater to the annual recharge of base flows (USAID, 2021). In addition, an estimated 1.3 billion tons of sediment is retained per year, ensuring sustained productivity of rice fields downstream. This retention also prevents approximately 795-1,258 tons of phosphorus per year from reaching Lake Kyoga, which prevents eutrophication and supports fisheries.

Natural vegetation also reduces sediment flowing into Lake Victoria and Lake Kyoga, whose headwaters originate from Mount Elgon. Furthermore, sediment retention prevents sediments from filling up Turkwel Gorge Dam, which stores and supplies water to its important hydroelectric facility and to irrigation systems in dry northwest Kenya. If this sediment were not being retained by the landscape, the landscape's replacement cost – i.e., the cost of constructing and maintaining sediment check-dams – is estimated at $1.85 billion per year.

Unpolluted water flowing through the landscape further supports agriculture in South Sudan, a sector that employs 80 percent of the country's workforce (AWF, 2021). The landscape also provides water, grazing, and browsing relish for wildlife throughout the year in the rangelands of both Uganda and South Sudan (UWA, 2015).

2 Tourism offers high potential for private sector investment.

This region is ripe for private sector investment in tourism, and a growing industry already exists in Uganda. Until recently, tourism in the northeastern Karamoja region of Uganda was under-developed and off the radar for even the most adventurous of tourists. The region was largely inaccessible by roads, isolated from the rest of Uganda, and tribal conflicts raised security concerns for potential travelers. However, newly paved roads, a chartered air service, the construction of safari lodges, and a return to peace across the region has resulted in a significant increase in the number of tourists to this remote wilderness. Today, tourism in Karamoja is centered on nature and nature-based activities.

In the war-torn nation of South Sudan, the tourism industry (as well as much of the wildlife) is essentially non-existent. However, the country is emerging from conflict and, with a peace deal in place, is focusing on diversifying revenues with the hope of growing tourism. Without the necessary investment, the industry will likely take decades to develop. However, there is great potential, and if wildlife landscapes are properly managed, they could provide income, jobs, and numerous valuable ecosystem services to the people of South Sudan.

THE COST OF INACTION

PROJECTED OUTCOMES BY 2050 IN A BUSINESS AS USUAL SCENARIO

TOP THREATS

1. Land conversion and degradation
2. Unsustainable resource and land use
3. *Impacts from climate change that will exacerbate threats*
   Drought, flooding, increased temperatures

STRESSES ON NATURAL ENVIRONMENT

4. Habitat loss and fragmentation
5. Land degradation through loss of natural vegetation and soil cover
6. Changes to mammals and other high-value species
7. Changes to freshwater systems

1 Land conversion and degradation

Population growth, insecurity, stock theft, and cultivation have increased sedentarization and reduced productive land for livestock (Bintoora, 2016). At the same time, livestock numbers are estimated to increase 65 percent and 224 percent in the Kenyan and Ugandan portions of the landscape respectively. While the trend is more uncertain for South Sudan, productivity of many grazing region is declining. Land conversion for subsistence agriculture is also on the rise; cropland expanded 5.39/ha/yr from 2015 to 2018.

2 Unsustainable resource and land use

Top threats include overharvesting of woody biomass (with demand predicted to increase by 35 percent by 2050) and hunting for local bushmeat consumption (with demand estimated to increase by 30 percent). Fuelwood harvest drives forest and woodland degradation, particularly in Uganda, where demand is growing from urban areas to the west, and in the Mount Elgon region of Kenya. Hunting – facilitated largely by insecurity and poor law enforcement – has also caused substantial declines in wildlife.

3 Climate change impacts

Of the four landscapes in this study, the Northern Savannas are predicted to experience the largest shifts in temperature and precipitation. Expected increase in annual precipitation from 2040-2060 is approximately 13 percent above historical averages. Also predicted: decreased June rainfall, significantly increased December to March rainfall, and a 2.7°C increase in mean annual temperature.

4 Habitat loss and fragmentation

An estimated increase in cultivation area – from 5.1 percent of the landscape in 2018 to 7.4 percent in 2050 – would mean the conversion of an additional 3 to 4 million hectares for livestock and farming. This will diminish and fragment habitat, reduce ecotourism opportunities, and reduce materials for harvesting. An estimated increase in land suitabillity for crops may also expand cultivation and reduce habitat.

5 Land degradation through loss of natural vegetation and soil cover

Projected increase in livestock numbers would lead to stocking densities beyond what the natural fodder can sustain. Land conversion and unsustainable use may also lead to land degradation, reducing the landscape's ability to prevent erosion and retain phosphorus and sediment. This will also diminish the landscape's ability to mitigate climate change through stored carbon.

6 Changes to mammals and other high-value species

Loss of habitat availability and connectivity will reduce wildlife biomass, increase genetic isolation of wild populations in protected areas, and reduce ability for wildlife to migrate in response to drought and climate change. Substantial declines in species richness are predicted from climate change alone, and this will be exacerbated by habitat loss and fragmentation.

7 Changes to freshwater systems

Increased pollution and sedimentation in waterways will negatively impact fisheries, irrigation, hydropower, freshwater availability, and sanitation and hygiene in Lakes Kyoga, Turkana, and Victoria catchments.

This synthesis assessed the current (2018) threats to wildlife and wildlife habitat and their projected impact by 2050 under a business as usual scenario. Note that projections consider climate change and assume full recovery from the current impacts of COVID-19.

IMPACT ON ECOSYSTEM SERVICES BY 2050	IMPACT ON ECONOMIC AND HUMAN WELL-BEING
8 Reduction in value of cultural services	12 No discernible change in ecotourism livelihoods
9 Increased cost due to loss of regulating capacity	13 Change in crop and livestock income
10 Increased cost due to loss of carbon storage capacity	14 Negative health impacts
11 Reduction in value of provisioning services	

8 Tourism revenue: -19.5 percent
Annual losses of $1.4 million in Uganda (22 percent decline); $280,000 in Kenya (12 percent decline).

Existence value: -2.5 percent
Expected decline in willingness to pay from $2 billion per year to $1.9 billion per year.

9 Erosion control capacity: -0.4 percent
An additional 4.8 million tons of sediment entering rivers and waterbodies would amount to an annual $6 million increase in maintenance and lost reservoir storage costs.

Water flow regulation capacity: -4.4 percent
Estimated loss of base flow is 205 million m^3 (2.5 percent of current), increasing annual replacement costs by $23 million.

Water quality: -1.3 percent
For the portion of the landscape that drains into Lake Kyoga, phosphorus export would increase by 4.7 percent, meaning water treatment costs would rise by $223,000.

10 Carbon storage: -0.3 percent
Predicted release of 0.5 percent (10.7 million tons) of carbon will cost the region an additional $560,000/yr in climate change impacts.

11 Follow up studies can determine the economic impact on provisioning services. Livestock production is projected to increase, while crop pollination and resources available for harvesting are projected to decline.

This assessment valued the cost of inaction associated with the potential loss of nine valuable ecosystem services. Further study is recommended to gauge the broader cost to the economy, jobs, and human well-being under a business as usual scenario. A few initial projections:

12 No discernible change in ecotourism livelihoods
Tourism revenue is already modest in the region, and the future of this sector is uncertain given insecurity and climate change. The business as usual scenario predicted no significant change in the number of jobs in the ecotourism sector. To achieve employment growth, more investment will be needed.

13 Change in crop and livestock income
Livestock numbers and croplands are both expected to increase, leading to decreased space available for wildlife. However, increased risk in this sector is also likely, due to (1) increased droughts, (2) increased competition for land, and (3) cattle rustling. Crop failures and livestock deaths increase people's reliance on bushmeat and other natural resources during and after droughts. Livestock increases could lead to degradation of new and already-overgrazed areas.

14 Negative health impacts
(1) Increased risk of zoonotic diseases, as increase in bushmeat hunting brings greater numbers of people in contact with meat from wild species; and (2) worsening human-wildlife conflict as populations of people and livestock increase and cultivation expands.

POLICY CONSIDERATIONS

Creating solutions for protecting natural capital will take all stakeholders working together across sectors and national boundaries. The team is currently engaging an array of stakeholders in a dialogue about policy priorities and in the development of a transboundary action plan.

Primary policy goals: Protect Mt Elgon's water tower and improve land-use and wildlife management in the KPAC.

1 Improve transboundary cooperation and coordination

The role of Mount Elgon as a transboundary water tower, supporting the Turkwel Basin and Lake Kyoga Basin, provides an important motivation for transboundary collaboration between Kenya and Uganda. The Turkwel River supports a 106 MW hydropower station and flows into the saline Lake Turkana through an arid environment as a major water resource for pastoralism and wildlife, as well as crop irrigation. The flow to Lake Kyoga similarly supports various livelihood types including fisheries.

To ensure that downstream needs are met for both countries, Kenya and Uganda must work together to ensure that Mount Elgon continues to be healthy and climate resilient to extreme rainfall events (both droughts and high-rainfall years) and rising temperature. A variety of studies to date have highlighted ecosystem-based climate adaptation solutions for Mount Elgon on both sides of the border. The four main climate hazards on Mount Elgon are landslides, drought, flooding, and soil erosion. Projects are ongoing to address these hazards. For example, IIED, IUCN, and Uganda's Ministry of Water and Environment are currently implementing a variety of interventions under the Ecosystem-based Adaptation in Mountain Ecosystems Project, building ecosystem management capacity in the communities and improving water retention using roadside drainage bunds, run-off retention drains and tree planting using an agroforestry approach. As part of the project, Uganda's Ministry of Water and Environment is also promoting better integration of ecosystem-based climate adaptation principles into policy and planning at the national level.

Mount Elgon, Uganda

PHOTO: MONIKA HRDINOVA

2 Develop public-private partnerships around insurance schemes for farmers in the Mount Elgon region

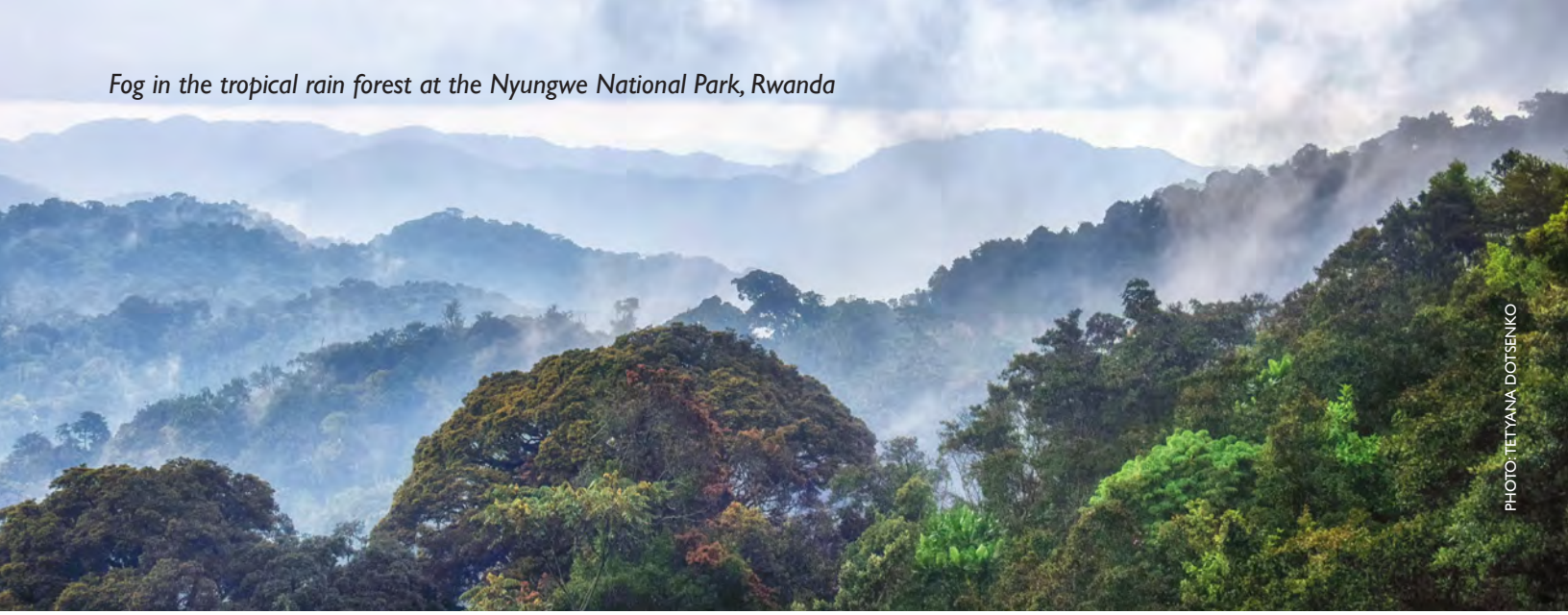
Mount Elgon is a key water tower for the Northern Savannas landscape, providing safeguards on water flow and sediment retention. However, due to its steep slopes, intense precipitation, and fertile lands supporting a dense population (1,000 people per km^2) in eastern Uganda, it is one of the most landslide-prone regions in Africa (Broeckx et al., 2019). Poor farming practices may contribute to the frequent landslides that cause damage and fatalities. There is an opportunity for Partner States (Kenya and Uganda) to develop partnerships with the private sector based on insurance schemes for farmers that cover restoration and reforestation (new carbon) and climate smart agriculture. The partnership could be modeled on that between the Government of Rwanda and the World Bank (Rutebuka, 2019).

3 Use CBNRM to ensure solutions that benefit both people and nature

As populations grow and climate change impacts intensify, land and resources grow scarcer and tolerance for wildlife and conservation could decrease, leading to a rise in human-wildlife conflict. Natural resource management strategies that benefit both people and nature will be critical. For example, the KPAC holds great potential to attract private sector investments that tie wildlife conservation to local community benefits, including through the use of CBNRM such as Community Wildlife Areas/Community Conservancies. To be effective in achieving conservation and sustainable development goals, CBNRM requires transboundary collaboration between Kenya, South Sudan, and Uganda, as well as multiple partnerships with local communities, civil society, and the private sector .

KEY STAKEHOLDER GROUPS

Stakeholder group	Call to action	Benefits to stakeholder
Wildlife managers	Strategies that strengthen CBNRM such as Community Wildlife Areas/Community conservancies; Transboundary (Kenya, South Sudan, Uganda) collaboration and multiple partnerships with local communities, civil society and the private sector to jointly seek creative nature-based solutions to the landscape's environment, economic, and social challenges	Conservancies would benefit communities, while providing a range of ecosystem services including space and security for wildlife. They would also shape a sustainable environment, with reduced inter-ethnic conflicts for grazing land and reduced human-wildlife conflict.
Small-scale agriculture	Reduce activities that accelerate erosion; engage in reforestation activities that prevent landslides; participate in insurance schemes and ecosystem-based adaptation activities	Sustainable livelihoods; new economic opportunities through carbon sequestration; reduced risk of landslides; development schemes, resilience to climate change
Agro-pastoralism	Adopt holistic management practices; engage in ecotourism; avoid land conversion to cropping; avoid overstocking	Improved pasture and stock quality; earnings from ecotourism; space and security for wildlife
Hydropower (large and small scale) and users of this power – especially Turkwel Dam	Advocate for transboundary cooperation for watershed management, focusing on constructive collaboration between Kenya and Uganda	Sustained water and power availability in the region
Tourism sector	Advocate to improve the status of protected areas in the central and southern parts of the landscape, especially around Mount Elgon and in the KPAC	Widened range of areas for ecotourism leading to expanded activities and improved employment
Transboundary leaders (EAC and transboundary protected area managers)	In Uganda and Kenya, focusing on the Mount Elgon area, enter into partnerships with the private sector to develop an insurance scheme for farmers that include coverage to support landscape restoration focusing on reforestation (new carbon) and climate smart agriculture In the KPAC area, support land use planning and wildlife management that ensures ecosystem services are sustained Support development in southern South Sudan portion of the landscape to reduce poaching in the protected areas	Improved NRM and coordination and collaboration between countries and across political boundaries
International donors/ international NGOs/ development partners	Work with communities, protected areas management, governments, the EAC, other donors and partners to support any or all of the above, especially in Mount Elgon and KPAC regions Support diversification of livelihoods of communities highly dependent on natural resources	Fulfill development and conservation agendas; improve the world



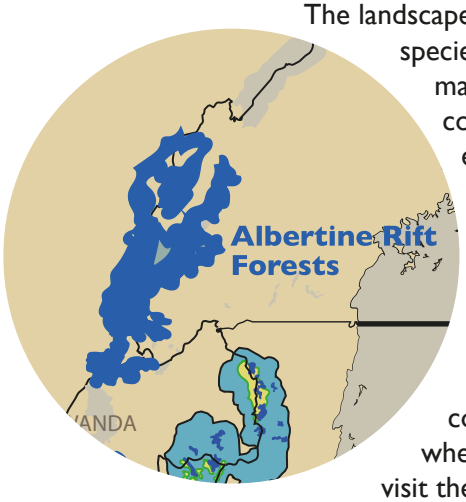
Fog in the tropical rain forest at the Nyungwe National Park, Rwanda

PHOTO: TETYANA DOTSENKO

IV.D ALBERTINE RIFT FORESTS

NATURE

The Albertine Rift Forests landscape contains some of the world's most diverse afromontane forests, with many endemic plants, mammals, and birds (Cunningham, 1996). The landscape hosts 52 percent of all bird species and 39 percent of all mammal species of the African continent, with more endemic and globally-threatened vertebrates than any other region in Africa (Plumptre et al. 2007).



Rwanda and Uganda are currently the only two countries in the world where tourists can safely visit the critically-endangered mountain gorilla *(Gorilla beringei beringei)*. Just over 1,000 mountain gorillas can be found in Volcanoes National Park in northwest Rwanda and Bwindi Impenetrable National Park in Uganda. This landscape is also home to the critically-endangered endemic plant *Diospyros katendei Verdc.*, which is found only in Kasyoha-Kitomi Central Forest Reserve.

These parks are becoming increasingly isolated in a matrix of agricultural fields and settlements. The only remaining connection between the national parks in northern Rwanda and southern Uganda is through corridors of forest that connect these parks to neighboring Virunga National Park in the DRC.

LANDSCAPE AT-A-GLANCE

- **Total population**: ~10M across Uganda, Rwanda, and Burundi; 97% rural

  Population density: Rwanda (512 people/km^2) and Burundi (449 people/km^2) are the most densely populated countries in mainland Africa (UN 2019). Density in Uganda is moderate at 222 people/km^2.
- **Land area:** 7,772 km^2
- **Area under protection**: Main protected areas include Kibale, Queen Elizabeth, Rwenzori Mountains, Mgahinga, and Bwindi Impenetrable National Parks in Uganda; Volcanoes and Nyungwe Forest National Parks in Rwanda; and Kibira National Park in Burundi. Together, these six national parks cover close to 600,000 hectares.
- **Important ecosystem assets:** High concentration of diverse and endemic species. It is most famous for its gorillas, which provide a lucrative but source of tourism revenue and a catalyst for additional tourism activities in the region source of tourism revenue.
- **Important transboundary assets**: The remaining afromontane forest in Uganda and Rwanda is largely connected via protected areas in the DRC. There is also the Nyungwe-Kibira transboundary area between Rwanda and Burundi.

Without this connection, these parks would become isolated forest patches. Nyungwe and Kibira National Parks in Rwanda and Burundi are contiguous and form part of the proposed Nyungwe-Kibira Transboundary Conservation Area (TFCA, IUCN ESARO, 2020), but there are no corridors that link these parks to other forested landscapes. Queen Elizabeth adjoins Kibale National Park to form a 180 km-long corridor for movement of wildlife between these two parks.

This landscape is an Endemic Bird Area that hosts restricted-range species, including monotypic endemic genera *Pseudocalyptomena, Graueria,* and *Hernitesis*. Nyungwe-Kibira forest is an important habitat for the endangered endemic Congo Bay-owl (*Phodilus prigoginei*) (Birdlife International, 2021).

NATURE'S BENEFICIARIES

Nature underpins the livelihoods and well-being of all of the nearly 10 million people living in this landscape. Following is a look at key stakeholder groups.

Smallholder farmers, hunter-gatherers, cattle keepers, and fishers

Smallholder farming and livestock rearing remain the dominant livelihood activities, despite increasing urbanization across all countries in the study area (Salerno et al., 2018). In Burundi, 85 percent of local communities rely on agriculture. Small-stock farming is important, as are dairy cattle in some areas. Households grow a variety of fruit and vegetables for household consumption, as well as for sale at market. The Twa (Burundi) and Batwa (Uganda) are hunter-gatherers who depend on provisioning food from forests. Forests play a major role in the social-economic development of Rwanda by providing goods and ecosystem services in addition to employment.

When it comes to income from harvested resources for communities in this landscape, charcoal production provides the largest percentage (61.8 percent), followed by wood production at (19.2 percent) (*Rwanda National Forestry Policy,2018*). In 2007, the value of firewood and charcoal totaled $122 million – about 5 percent of the national GDP.

Commercial agriculture sector

The principal crops are coffee and tea, and conservation areas are surrounded by agricultural land and large multinational tea estates.

Tourism sector

The total direct contribution to GDP of nature-based tourism in the landscape was estimated at $50.3 million in 2018. Gorilla trekking is considered an important catalyst for additional tourism activities in the region.

Other private sectors

Other private sector industries that rely on access to natural capital include agriculture, fishing, mining, and oil in the Lake Edward-Albert Basin.

NATURE'S GUARDIANS

There are a range of stakeholders at the local, national, regional, and global levels who influence stewardship of natural capital in this landscape.

Community conservancies

In Rwanda: From 2005-2017, the Rwanda Development Board invested $1 million in 152 community-based conservation projects and integrated conservation and development projects around Nyungwe National Park as part of a revenue sharing scheme (RSS) to strengthen protected area management (Imanishimwe et al., 2019).

In Uganda: The Uganda Wildlife Authority developed community conservation in the 1990s to harmonize the relationship between park managers and neighboring communities, allowing these communities access to protected area resources. For example, in Bwindi Impenetrable National Park, beekeeping for honey collection is the most lucrative of several multiple use program activities for local people.

National and regional policymakers

The EAC and its Partner States, including Burundi, Rwanda, and Uganda, play a key role in stewarding the landscape's natural capital. The National Institute for Environment and Conservation of Nature in Burundi, the Rwanda Development Board, and the Uganda Wildlife Authority oversee protected area management, employing rangers and other natural resource managers and creating policies that govern land use and development.

International development partners and NGOs

A range of bilateral, multilateral, and non-governmental organizations are already investing in generating and applying evidence on natural capital in the Albertine region. Since 2008, ARCOS Network has been managing a regional biodiversity information system (http://arbims.arcosnetwork.org/), which has catalyzed efforts to collect and use biodiversity data.

NATURAL CAPITAL VALUE

This is an overview of the estimated value of each ecosystem service, as well as key insights to guide stakeholders toward improving protection of the natural capital that provides these services. The full assessment contains further details and analysis. **Total estimated value**: $1,530/ha/yr on average to East Africa; more than $54,800/ha/yr globally.

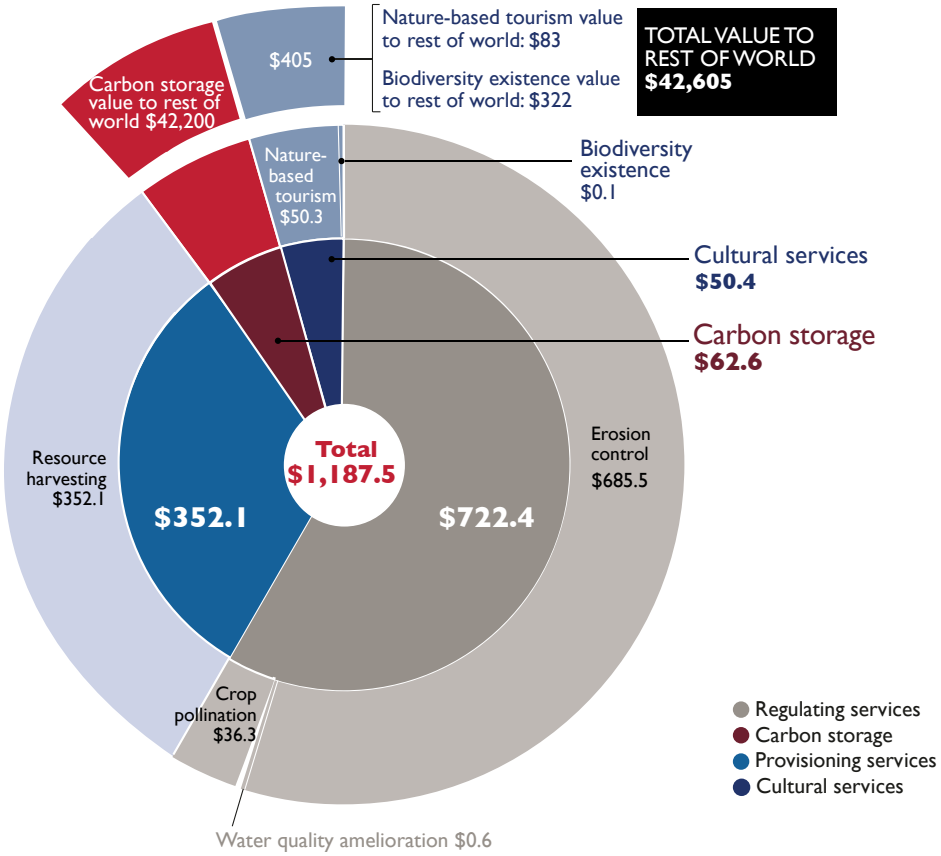


Figure 8. U.S. dollar value of ecosystem services in millions per year in Albertine Rift Forests

REGULATING SERVICES

Water quality amelioration: $600,000/yr *(in avoided costs from reduction of phosphorus loadings; if available landscape is converted to agriculture, treatment costs could rise to $682,469/yr)*

Erosion control: $685.5 *(through retention of sediment)*

Crop pollination: $36.3M/yr *(estimated increase in crop production)*

CARBON STORAGE

Regional value: $62.6M/yr *(in avoided costs due to storage of an estimated 643 million tons of carbon)*

Value to rest of world: $42.2B/yr *(in avoided costs from storage of same stocks)*

PROVISIONING SERVICES

Harvested resources: $352.1M/year

CULTURAL SERVICES

Nature-based tourism: $50.3M
(sector also creates 104,980 jobs for the region – 18,000 in Burundi; 48,180 in Rwanda; 28,000 in Uganda)

Biodiversity existence: $100,000/yr to regional community
($322M/yr to rest of world)

KEY INSIGHTS

Erosion control and material harvested from nature are the most important ecosystem services.

Although the Albertine Rift Forests are renowned globally for their rich biodiversity, the value of this landscape to local livelihoods and well-being far outweighs the economic value provided by tourism. Aside from carbon sequestration, the highest economic value lies in sediment retention. The high rainfall (1,000-1,400 mm per year) across most of this region, often falling on steep slopes, results in a high potential for soil erosion. Natural vegetation here retains 619 tons of sediments per hectare per year, saving the landscape an estimated $685.5 million per year in erosion control.

Harvested resources are also key to local livelihoods. Rural households secure income by cultivating crops and raising livestock. A wide variety of wild resources are harvested for nutrition and health, energy, and raw materials from the forested habitats that remain in this region. Woody resources are particularly important, as more than 95 percent of households use firewood or charcoal as a main fuel source. Collection of wild fruits, vegetables, and mushrooms is also important for livelihoods. Access to forest products has been shown to increase household incomes by up to 35 percent per year (Albertine Rift Program WCS, 2021).


Man and cow, Uganda
PHOTO: JASON HOUSTON

2 Global value of biodiversity existence for this landscape is high.

Valued at $322 million per year, this landscape ranks exceptionally high as a global conservation priority. Because of its endemic and globally-threatened species, the global conservation community started an eco-region conservation planning process across the landscape in Uganda, Rwanda, Burundi, DRC, and Tanzania in 2003 (GoU, 2007). Transboundary policies that would ensure connectivity of habitats that sustain iconic gorilla populations, based on protected area conservation, would be more sustainable than maintaining business as usual.

3 Gorilla trekking is an important catalyst for regional tourism.

Tourists who primarily come to see this landscape's mountain gorillas also visit other wildlife areas and tourist attractions, spending time hiking in the Rwenzori Mountains National Park (Uganda), birdwatching in Nyungwe National Park (Rwanda), or going on safari to spot large game in Queen Elizabeth National Park (Uganda). Parks considered most important for the protection of mountain gorillas, Volcanoes National Park (Rwanda) and Mgahinga Gorilla National Park (Uganda), had the highest tourism value at $837 per ha per year. If current gorilla conservation efforts remain effective, annual tourism value could increase by $5.3 million in Rwanda and $4.2 million in Uganda by 2050. In contrast, annual tourism value is predicted to decline by $400,000 in Burundi due to poorly developed tourism products, insecurity, and forest encroachment.

THE COST OF INACTION

PROJECTED OUTCOMES BY 2050 IN A BUSINESS AS USUAL SCENARIO

TOP THREATS

1. Land conversion
2. Unsustainable resource and land use
3. *Impacts from climate change that will exacerbate threats*
   Temperature and precipitation changes

STRESSES ON NATURAL ENVIRONMENT

4. Loss of vegetation and soil cover
5. Habitat loss, fragmentation, and degradation
6. Changes to primates and other high-value species
7. Changes to freshwater systems

1 Land conversion

Ever increasing food demand has driven increased land cultivation (Salerno et al., 2018). Intensive cropping has already expanded right to the edges of protected areas. Farming on steep slopes is also impacting forest cover, with the Global Forest Change dataset indicating a clear upsurge in deforestation rates since 2014 (USAID, 2021). Rising urbanization is causing increase in production of charcoal, as well as bricks for building materials – both of which put further pressure on forests. As pressure grows on protected area borders, human-wildlife conflict is also a growing challenge (Hill et al., 2002b; Tolbert et al., 2019).

2 Unsustainable resource and land use

Fuelwood scarcity is driving illegal harvesting of wood from protected areas (Harrison et al., 2015; Plumptre et al., 2016). Over-harvesting of other forest resources have also caused degradation of key habitats. With population growth, demand for woody resources could increase by approximately 75 percent. Excessive hunting pressure – including rampant bushmeat offtake, inadequate conservation law enforce-ment, and commercial hunting for illegal wildlife trade – has also had a severe impact on wildlife. Livestock grazing an additional threat to wildlife, most notably in Queen Elizabeth National Park.

3 Temperature and precipitation changes

Total annual precipitation is expected to increase by 1.9 percent by 2040-2060, and mean annual temperature by 2.7°C. The August-November short rainy season is predicted to get wetter, with increased risk of flash floods and landslides. The long rainy season is predicted to get marginally drier.

4 Loss of vegetation and soil cover

Approximately 89,000 ha of forest could be lost (15.5 percent of existing forest cover). Due to the landscape's extreme slopes, deforestation would lead quickly to high levels of erosion (USAID, 2021).

5 Habitat loss, fragmentation, and degradation

Certain protected areas are already totally isolated due to cultivation, and landscape connectivity could be further compromised, threatening the viability of wildlife populations (USAID, 2021). Forest loss will impact the exceptionally high number of IUCN red-listed species found in the landscape (Plumptre et al., 2016). As climate changes, models predict increased suitability for most crop species, which will increase land conversion and habitat loss, particularly in higher-lying protected areas, which currently have low suitability for cultivation.

6 Changes to primates and other high-value species

Intensive cultivation around protected areas will prevent high-value species from moving to escape the pressures of climate change (USAID, 2021). Ongoing habitat conversion in the DRC may erode the critical landscape corridors between Rwanda, Uganda, and the DRC.

7 Changes to freshwater systems

Freshwater systems will become more polluted due to increased cultivation of land adjacent to the wildlife landscapes of Rwanda and Uganda, and to a lesser extent Burundi where farmers apply less fertilizer.

This synthesis assessed the current (2018) threats to wildlife and wildlife habitat and their projected impact by 2050 under a business as usual scenario. Note that projections consider climate change and assume full recovery from the current impacts of COVID-19.

IMPACT ON ECOSYSTEM SERVICES BY 2050	IMPACT ON ECONOMIC AND HUMAN WELL-BEING
8 Reduction in value of cultural services	12 Impact on jobs and livelihoods
9 Increased cost due to loss of regulating capacity	13 Change in food security
10 Increased cost due to loss of carbon storage capacity	14 Decreased water availability and quality
11 Reduction in value of provisioning services	15 Negative health impacts

8 Tourism revenue: +18.7 percent
If gorilla conservation efforts remain effective: $5.3 million increase in Rwanda; $4.2 million increase in Uganda. However, decline predicted in Burundi.

Existence value: -7.9 percent
A decline in willingness to pay from $322.2 million (current value) to $296.7 million by 2050.

9 Erosion control capacity: - 1.3 percent
An additional 6.5 million tons of sediment entering rivers and waterbodies would amount to an annual $8 million increase in treatment costs.

Water flow regulation capacity: -3.1 percent
Baseflow predicted to decline 3.1 percent. Reduced capacity to regulate water flow will impact both households and businesses, with the cost of reservoir storage to retain this amount of water rising by $13 million.

Water quality: -39.4 percent
Addition of 179,000 tons of phosphorus export over the current landscape, leading to an increase of $338,000 in annual water treatment costs due to nutrient pollution.

10 Carbon storage: -7.6 percent
Reduced capacity to store carbon will increase mitigation costs by $4.7 million regionally and $3.2 billion globally.

11 Follow up studies can better determine the economic impact on provisioning services. Livestock production is projected to increase, while crop pollination and resources available for harvesting are projected to decline.

This assessment valued the cost of inaction associated with the potential loss of nine valuable ecosystem services. Further study is recommended to gauge the broader cost to the economy, jobs, and human well-being under a business as usual scenario. A few initial projections:

12 Impact on jobs and livelihoods
If gorilla conservation remains effective, nature-based tourism is projected to increase (except in Burundi), although it may plateau around 2040 due to ongoing population growth and encroachment pressures on remaining habitat. Tourism benefits will have an estimated global value of $99.1 million per year – a 19 percent increase from 2018 – providing more than 11,500 new jobs to the region.

13 Change in food security
The 15.5 percent loss of forest cover means reduced availability of forest resources, including woody biomass, wild foods, and medicine, which will impact food security and nature-based livelihoods. This may be supplemented by agricultural expansion and other development efforts in and around the landscape.

14 Decreased water availability / quality
There will be reduced support for fisheries and water, sanitation, and hygiene in the Lake Edward and Lake Albert basins, whose catchment covers an area of approximately 622,472 km² and supports a population of approximately 12 million.

15 Negative health impacts
Increase in zoonotic disease from compromised wildlife; public health burden from rising pollution and bushmeat consumption; increase in violence due to human-wildlife conflict.

POLICY CONSIDERATIONS

Creating solutions for protecting natural capital will take all stakeholders working together across sectors and national boundaries. The team is currently engaging an array of stakeholders in a dialogue about policy priorities and in the development of a transboundary action plan.

Primary policy goals: Continue the positive trajectory of gorilla conservation efforts, while also prioritizing forest cover (especially on slopes) to maintain erosion control.

Following are recommended focal areas for discussion as stakeholders consider strategies for achieving these goals.

1 Strengthening RSS that benefit communities and nature

RSS around protected areas provide local communities with incentives to support conservation, particularly when they might be adversely impacted by the loss of nature through reduced livelihoods or greater susceptibility to human-wildlife conflict. There are a number of existing models that can be strengthened or replicated. Following are just a few:

- **Burundi:** Although there is no record of formal RSS in Burundi, there are local groups known as *Association Dukingiribidukikije*. Created in 2012 by local volunteers, these groups are actively protecting the environment, while seeking solutions to address poverty (Fuhnwi, 2017).
- **Rwanda:** The government of Rwanda has created tourism revenue sharing programs to advance poverty alleviation, health improvement, and economic empowerment. To date, the government has invested $5.3 million in rural communities. In 2019, RSS were increased to 10 percent of tourism revenue, so that out of $400 million in total revenue, communities received $40 million (Rwanda's 6th national report to CBD). The Sabyinyo Community Livelihood Association (SACOLA), located at the foothills of the Volcanoes National Park, was the first RSS engagement between government and community. Using tourism revenue, SACOLA has supported over 5,800 households. Since 2004, SACOLA has generated jobs, created community cooperatives, promoted tourism products, undertaken profit sharing with surrounding communities, and constructed houses for the poor and vulnerable, among other activities.
- **Uganda**: An RSS was established in 1995 at Bwindi Impenetrable National Park, in which 20 percent of total revenue was shared with park-adjacent communities. The Uganda Wildlife Authority has since developed national revenue sharing guidelines applicable to all of its parks (Franks & Twinamatsiko, 2017). The scheme is generating between $195,000 and $260,000 annually in total revenue to be shared – enough to ensure that people living in 'front-line' villages would earn approximately $10/year. Despite the relatively low income, this project is showing a positive impact on conservation and the communities (Franks & Twinamatsiko, 2017).

2 Tapping into global willingness to pay for wildlife and habitat conservation and carbon sequestration

The global community has a vested interest in addressing the species extinction crisis, conserving this important landscape for future generations, and mitigating climate change. Tapping into this community's willingness to pay for conservation and forest management should be a key strategy. However, challenges lie with designing measures that will allow for this transfer of value, and ensure funds sourced from the global community are indeed used to fund conservation activities. Investment would come from international donors, but community ownership of the resulting nature conservation strategies will be key to success. In addition, transboundary and regional coordination on PES initiatives like REDD+ will be critical to avoid any time-consuming competition for pooled regional resources.

One way to engage the international community and tap into biodiversity existence value is through engagement in international agreements and treaties. Rwanda has ratified various multilateral environmental agreements that promote proactive, sustainable environmental management and biodiversity conservation. These include the UN Convention on Biological Diversity (CBD), the Convention to Combat Desertification, the Framework Convention on Climate Change (UNFCCC), and the Kyoto Protocol. In 2016, Rwanda also signed the Paris Agreement on climate change and ratified it.

Forest mapping is also a fundamental step toward engaging with the international community on PES and REDD+. Entering carbon markets in particular requires understanding each country's carbon stocks. In the 2010s, Rwanda conducted two forest mapping efforts, resulting

in two reports (2012, 2019). The 2012 report measured forest cover as 24.5 percent of the country's total land area. Rwanda's 2020 Vision, finalized in July 2000, was to increase forest cover to 30 percent of its total land area. The 2019 report indicated that forest now covers 30.4 percent of Rwanda's total land area. This increase in forest cover has enhanced the carbon storage and sequestration potential in the country.

3 Investing in transboundary tourism models based on gorilla conservation

Due to the inextricable link between gorillas and tourism, the loss of one will lead to the collapse of the other. Fortunately, gorilla tourism is currently well managed, but continued investment in the sector's infrastructure, as well as in habitat conservation, are key to long term sustainability. Currently, connectivity of suitable gorilla habitats depends on a path through the DRC – an area under threat from agriculture and mining. A sustainable investment strategy will require enhanced collaboration between Burundi, Rwanda, Uganda, and the DRC. Because gorilla conservation catalyzes tourism to other sites throughout the region, transboundary strategies will benefit all countries, as well as local community livelihoods that are tied to nature-based tourism.

KEY STAKEHOLDER GROUPS

Stakeholder group	Call to action	Benefits to stakeholder
Smallholder farmers, hunter-gatherers, cattle keepers, and fishers, as well as community conservancies	Restore and safeguard environments that support livelihoods, taking into account the needs of women,and the vulnerable groups. Harvest resources sustainably. Advocate for RSS and PES to promote sustainable resource use.	Access to natural resources; Additional sources of income or access to markets become available
Commercial agriculture sector	Harness opportunities to funds that support community initiatives through measures like water funds to restore and safeguard natural vegetation. Support strategies related to PES for erosion and water quality control around protected area boundaries and downstream.	Natural vegetation sustains the high value of soil erosion control and flow regulation provided by the landscape Sustainable provision of water and pollination, as well as soil erosion control
Tourism sector	• Advocate for RSS and PES to promote sustainable resource use • Continue to support investment in the sector's infrastructure, as well as in habitat conservation • Prepare for impacts of climate change on gorillas and other important flora and fauna	Continued expansion of gorilla tourism and visits to other parks
Other private sectors	Support strategies related to PES for erosion and water quality control downstream; invest in green infrastructure	Lack of sedimentation and eutrophication in lakes, rivers, and dams
National and regional policymakers	• Enhance share of National Parks' financial revenue earned through tourism or other activities with local communities by expanding models for RSS and PES that work at country and transboundary levels • Integrate the economic value of biodiversity and ecosystems into national accounts, local development strategies and planning processes. • Engage in international agreements and treaties	Continuity of regulating services that provide water, filter pollutants, and reduce soil erosion – all of which are critical to avoiding loss of productivity and revenue
International development partners and NGOs	Create policies that incentivize sustainable land use (zoning, alternative livelihoods) and protect land cover; policies on sustainable tourism	Avoided costs of mitigating soil erosion, water scarcity or pollution, climate change damage

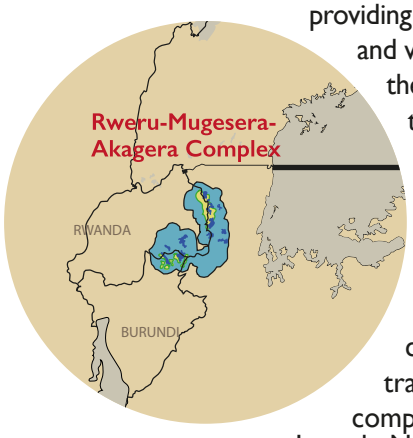
Hippopotamus (Hippopotamus amphibius), Akagera National Park, Rwanda

PHOTO: ROSTASEDLACEK

IV.E RWERU-MUGESERA-AKAGERA WETLAND SYSTEM

NATURE

The Rweru-Mugesera-Akagera wetland complex in Burundi, Rwanda, and Tanzania is one of the largest wetland areas in the basins surrounding Lake Victoria. Large areas of papyrus swamps and several open water lakes cover this area, providing home to a wide array of birds and wildlife. Evergreen bushland is the dominant natural vegetation type in the terrestrial areas around the wetlands, interspersed with grassland. Only small patches of forest occur.



This landscape comprises interconnected transboundary wetland complexes encompassing the Lacs du Nord-protected landscape in Burundi, the Akagera National Park in Rwanda, and the wetland ecosystem of Burigi-Chato National Park in Tanzania. For this study, delineation of this landscape extended 20 km from the wetlands into the surrounding area. Beyond the landscape, the Kagera River and its tributaries contribute 7.5 billion m^3 of water per annum into Lake Victoria (Hagai, 2019), supporting 40 million people.

The swamp-fringed lakes contain incredible biodiversity and rare species like the shoebill stork. More than 400 bird species have been recorded here. Akagera National Park supports a rich, recovering wildlife population that

LANDSCAPE AT-A-GLANCE

- **Total population:** 7.5 million (5.4M in Rwanda; 1M in Tanzania; 1.1M in Burundi)
- **Average population density:** Very high ~3,495 people/km^2 (largely due to proximity of Kigali in Rwanda)
- **Rural population:** 99% in Burundi; 88% in Rwanda; 99% in Tanzania
- **Land area:** 2,146 km^2
- **Area under protection:** Akagera National Park in Rwanda, one of the largest protected wetlands in East Africa (1,122 km^2); Lacs du Nord (187 km^2) in Burundi; Burigi-Chato National Park (4,707 km^2) in Tanzania
- **Important transboundary assets:** Finding transboundary solutions to conserving these wetlands is critical to the well-being of millions of people who live in and around this landscape. The wetland complex is part of the Kagera River Basin that contributes 7.5 billion m^3 of water per annum into Lake Victoria (Hagai, 2019). The nearly 40 million people the lake supports comprise one-third of the region's population (IPSI, 2018).

includes reintroduced populations of lion and black rhinoceros, which makes it the only Big Five park in Rwanda and a tourism draw for international gorilla visitors. The restoration of this park from its previously degraded status 20 years ago has been a success story for Rwanda and the region. Populations of large wildlife species such as elephant and buffalo also remain in Tanzania's Ibanda-Kyerwa National Park and Kimisi Game Reserve (Masalu, 2008).

NATURE'S BENEFICIARIES

Nature underpins the livelihoods and well-being of all of the 7.5 million people living within this landscape, as well as the additional 32.5 million people living in areas around Lake Victoria that are impacted by the health of these wetlands. Following is a look at key stakeholder groups.

Smallholder farmers, cattle keepers, fishers, and handicraft artisans

Agriculture is the dominant livelihood activity. Pastoral and agro-pastoral groups are present and most households own some livestock (FEWS NET, 2012). The southeastern region of Rwanda, northeastern region of Burundi, and northwestern region of Tanzania have become known for the large-scale production of bananas, which provides a source of food and income for most households. Market access is good throughout this region and other cash crops include beans, maize, cassava, and in some areas, coffee. Particularly in the Rwandan portion of the landscape, wetlands have also become the sites of large-scale agro-industrial developments like sugar cane plantations, resulting in substantial habitat loss (Nsengimana, Weihler & Kaplin, 2017).

The landscape's fisheries support more than three million livelihoods and bring in $500 million in revenue annually (WB, 2016). Local communities depend on natural capital in numerous other ways, including water for domestic use, rice growing, cattle grazing, raw materials for handicraft-making, and medicinal plants.

Energy sector and national water supply agencies

The wetland supports the 80 MW Regional Rusumo Falls Hydro-electric Project. This is located at Rusumo Falls along the Kagera River on the border between Rwanda and Tanzania and about 25 km downstream of Burundi. Downstream, the landscape provides the largest inflow into Lake Victoria and therefore impacts water supply for major urban centers like Kampala, Mwanza, and Kisumu. The invasive water hyacinth weed and pollutants flowing into this lake from the wetland affect water quality and therefore increase costs of water treatment for supply to these urban centers.

Tourism sector

Nature-based tourism directly contributed $5.3 million to GDP in 2018. The biggest contribution (49 percent) of this income was from Akagera National Park, tropical Africa's largest protected wetland.

Other private sectors

There are several other private sector industries that rely on access to natural capital. These include agriculture, fishing (within the wetland complex, along the Kagera River, and downstream in Lake Victoria), and mining.

NATURE'S GUARDIANS

There are a range of stakeholders at the local, national, regional, and global levels, who influence stewardship of natural capital in this landscape.

Community groups

Co-management initiatives – where the community collaborates with the Lake Victoria Environmental Management Program (LVEMP) – also support watershed management.

National and regional policymakers

The EAC, Lake Victoria Basin Commission, and Partner States, including Burundi, Rwanda (REMA), Tanzania (EMA), Kenya (NEMA), and Uganda (NEMA), play a key role in stewarding the region's natural capital.

International development partners and NGOs

LVEMP is conducting a program to revive the basin by restoring livelihoods, which involves communities in all five countries in watershed management and land rehabilitation. A total of 600 community-driven development projects involving 200,000 people are getting support for environment-friendly livelihoods.

NATURAL CAPITAL VALUE

This is an overview of the estimated value of each ecosystem service, as well as key insights to guide stakeholders toward improving protection of the natural capital that provides these services. The full assessment contains further details and analysis. **Total estimated value**: $300/ha/yr on average to East Africa; more than $34,600/ha/yr globally.

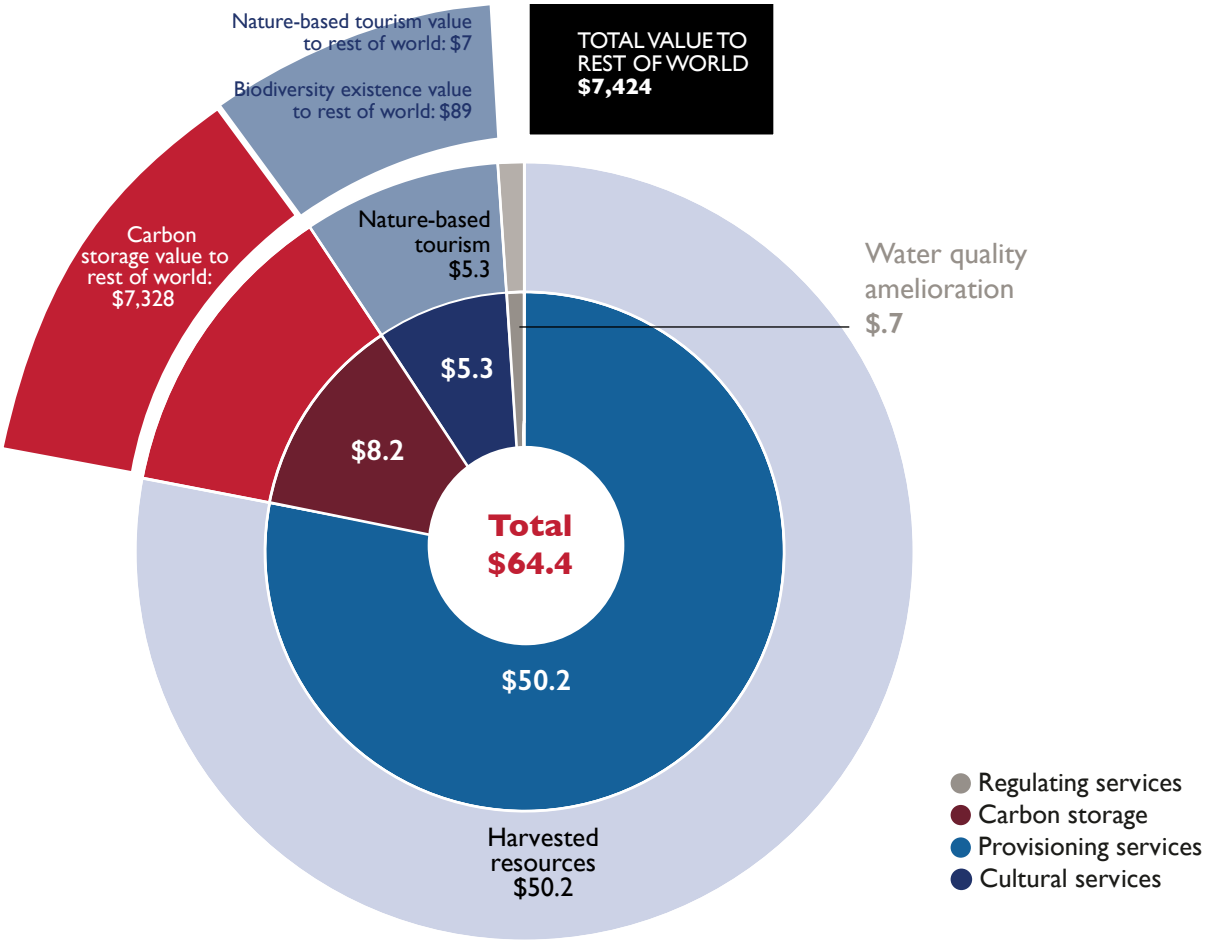


Figure 9. U.S. dollar value of ecosystem services in millions per year in Rweru-Mugesera-Akagera Wetland System

REGULATING SERVICES

Water quality amelioration: *$0.7M/yr*

PROVISIONING SERVICES

Harvested resources: $50.2M *($12.4M in Burundi; $26.1M in Rwanda; $11.7M in Tanzania)*

CARBON STORAGE

Regional value: $8.2M/yr *(in avoided costs due to storage of an estimated 92M tons of carbon)*

Value to rest of world: $7.33B/yr *(in avoided costs from storage of same stocks)*

CULTURAL SERVICES

Nature-based tourism: $5.3M/yr *($4.5M and 28,800 jobs in Rwanda; $0.7M and 260 jobs in Tanzania; $0.08 and 16,703 jobs in Burundi)*

KEY INSIGHTS

1 Harvested material is the most important ecosystem service.

Although wetlands are important for providing buffer, to flooding or overflow plains, reducing maximal flow rate, during the rainy season, and maintaining relatively high flow rates during the dry season, this wetland system is most valuable to the surrounding communities through provision of natural material for food and building. At $50.2 million, these provisional service, were 10 times more valuable than nature tourism at $5. 3 million in 2018 (USAID, 2021).

2 Sediment and phosphorus retention support fisheries in Lake Victoria.

Downstream from this landscape in Lake Victoria, fisheries support more than three million livelihood, and accrue $500 million in revenues annually (WB, 2016). The catchment areas of the wetlands play a significant role in preventing excess nutrients from reaching this important lake by capturing 2,700 tons of phosphorus and 7,000 ton, of nitrogen per year. If these nutrient loads reached the lake, water quality amelioration costs would be an estimated $726,000 per year (USAID, 2021).

3 Tourism has great potential in this wetland.

The Burundi-Rwanda-Tanzania wetland confluence shows great potential as a growth area for tourism. Rwanda's Akagera National Park, whose northern section shares a border with Tanzania. 's Ibanda Game Reserve, is currently the country', most visited national park. Akagera National Park generated $I million in 2018 from 44,000 largely (60 percent) local tourists. The Burundi portion of the wetland has the Lacs du Nord protected area, which earn, $0.03 million per year, while Ibanda-Kyerwa National Park in Tanzania's portion has minimal tourist activities. This wetland system is crucial for the protection of birdlife and supports a number of globally threatened species and restricted range species. The transboundary 100km^2 Lake Rweru in northern Burundi and south eastern Rwanda is the source of the Kagera River that arises from the northern part of the lake on the Rwandan side. Eighty percent of the lake is in Burundi and provides an opportunity for nature tourism.

In 2018, while global tourism was recording on average 6 percent growth, the sector in Tanzania experienced 13 percent growth. In tlhat year, there were 1.5 million visitors and $24 billion in revenue. The government of Tanzania upgraded Ibanda-Kyerwa from a game reserve to a national park.

PHOTO: BGSTOCK72

Akagera National Park in Rwanda

THE COST OF INACTION

PROJECTED OUTCOMES BY 2050 IN A BUSINESS AS USUAL SCENARIO

TOP THREATS

1. Reduction and fragmentation of wetland habitat
2. Over-extraction of natural resources
3. *Impacts from climate change that will exacerbate threats*
   Temperature and precipitation changes

STRESSES ON NATURAL ENVIRONMENT

4. Changes in habitat type, connectivity, and biodiversity
5. Changes in aquatic flora
6. Changes in vegetative and soil cover
7. Changes in hunting pressure on wildlife populations
8. Changes in freshwater quality, quantity, and flow

1 Reduction and fragmentation of wetland habitat

Fertile soils and enhanced water availability throughout the year make wetlands attractive sites for cultivation (Dixon & Wood, 2003; Khan et al., 2019), causing extensive conversion of habitats. Ongoing population growth and increased scarcity of land have also pushed people into more marginal areas (Dixon & Wood, 2003). Urbanization and infrastructure development are also key threats.

2 Over-extraction of natural resources

Extensive use of reeds and sedges is a distinguishing feature of this landscape, with resources extracted for handicrafts, building, food, and medicine. It is estimated that demand for papyrus from communities surrounding the wetlands will increase by 84 percent by 2050 in a business as usual scenario, which could have a substantial impact on papyrus stocks. Bushmeat is also harvested for consumption and sale, with 7 percent of households harvesting small mammals and birds. In Burundi, fishing is extensive, with catch totaling 3,600 tons in 2018 (Ministry of Environment Agriculture and Livestock, 2020). Demand for fish is predicted to rise, with a 113 percent projected increase by 2050.

3 Temperature and precipitation changes

Mean annual precipitation will increase by only 9 mm. Rainfall will decline 6-8 percent (mostly in August-September), but will increase 12-15 percent in the December - January wet season. Mean annual temperature is expected to increase by 2.7°C on average, with an increase by at least 2.8°C in June-October.

4 Changes in habitat type, connectivity, and biodiversity

Approximately 30 percent of swampland (90,000 ha) has been lost to cultivation in the Rwandan portion of the Akagera Basin (Republic of Rwanda, 2010). Remnants of non-aquatic natural habitat are limited to the remaining portion of Akagera National Park and surrounding areas, as well as parts of the Tanzanian portion of the landscape.

5 Changes in aquatic flora

Invasive species add to habitat degradation. Water hyacinth has spread extensively (across an estimated 100,000 ha), displacing native papyrus vegetation, invading open water and contributing to reduced water levels in lakes and within Akagera National Park.

6 Changes in vegetative and soil cover

Vegetation is being converted to numerous other land uses as a result of several pressures. Forest, woodland, and swamp are being converted at a rate of approximately 500-1,000 ha per year.

7 Changes in hunting pressure on wildlife

Wildlife are under threat from hunting and habitat conversion. Though enforcement has reduced hunting pressure in Akagera National Park (Apio et al., 2015), only a few wildlife species live outside the park.

8 Changes in freshwater quality, quantity, and flow

Expanded cultivation degrades wetlands through increased export of sediments and nutrients (Khan et al., 2019; Wasige et al., 2012). Urbanization drives toxic chemical runoff in waterways (Nabahungu, 2012). The invasive water hyacinth has also reduced water availability and filtration capacity.

This synthesis assessed the current (2018) threats to wildlife and wildlife habitat and their projected impact by 2050 under a business as usual scenario. Note that projections consider climate change and assume full recovery from the current impacts of COVID-19.

IMPACT ON ECOSYSTEM SERVICES BY 2050	IMPACT ON ECONOMIC AND HUMAN WELL-BEING
9 Reduction in value of cultural services	13 Negative impact on livelihoods
10 Potential increase in cost due to loss of regulating capacity	14 Reduction in food and water security
11 Increased cost due to loss of carbon storage capacity	15 Negative health impacts
12 Potential reduction in value of provisioning services	

9 Tourism revenue: +1.8 percent

This assumes Akagera National Park continues to be effectively managed. Value will plateau around 2040 due to limited size of park and loss of wildlife attractions elsewhere in wetlands. (Increase is in Rwanda; estimated revenue decline of 9 percent in Tanzania and 8 percent in Burundi.)

10 Capacity to maintain water quality and quantity: decrease (more study needed)

Continued land conversion to agriculture and intensification of cultivation will lead to greater sediment and nutrient runoff into wetlands. Increased water abstraction to meet demands by industry and growing population could lead to substantial reduction in available water. Population growth will lead to more sewage and other contaminants entering the system. Papyrus swamps play a key role in removing sediments, nutrients, and other pollutants. However, as vegetation is removed or outcompeted by the invasive water hyacinth, the ecological function of the wetland system could be compromised, creating greater costs for water treatment infrastructure.

11 Carbon storage: -1.5 percent

Wetland degradation is expected to increase the severity of local and global climate change. Carbon storage could decline with a release of 5.9 MtC, representing an increase of $110,000 in damages.

12 Follow up studies can determine the economic impact on provisioning services. Livestock production is projected to increase, while crop pollination and resources available for harvesting are projected to decline.

This assessment valued the cost of inaction associated with the potential loss of nine valuable ecosystem services. Further study is recommended to gauge the broader cost to the economy, jobs, and human well-being under a business as usual scenario. A few initial projections:

13 Negative impact on livelihoods

The Kagera River inflow to Lake Victoria supports an estimated 153,066 fisherfolk and 798,000 jobs in the fishing industry (for Kenya alone). These livelihoods are at risk of disappearing as water quality and fisheries decline. 80 percent of tourism jobs in Burundi and 8 percent in Tanzania could be lost, while Rwanda would see an increase in 46 percent due to investments in the landscape.

14 Change in food security

With demand for fish predicted to increase by 113 percent, people may be unable to meet their nutritional needs. As invasive species and eutrophication threaten the integrity of the wetland to regulate water quality, people may become water insecure.

15 Negative health impacts

The Akagera River is highly polluted with nutrients beyond the recommended level for aquatic life development in fresh water (Wali et al., 2011). Also, schistosomiasis (Bilharzia) risk is high in the wetlands, where infection is transmitted by snails living in the water. This is a risk to socio-economic development and quality of life. Though data were not available, a recent assessment suggests that eliminating sickness and death from bilharzia and soil-transmitted helminthiasis in Rwanda by 2030 could boost the countries' Gross Domestic Product (GDP) by $0.4bn (Kuteesa, 2020).

POLICY CONSIDERATIONS

Creating solutions for protecting natural capital will take all stakeholders working together across sectors and national boundaries. The team is currently engaging an array of stakeholders in a dialogue about policy priorities and in the development of a transboundary action plan.

Primary policy goals: Reduce unsustainable resource and land use and clear invasive alien hyacinth.

The wetland's potential economic and ecological value has been eroded by the encroachment of agriculture and livestock, overharvesting, and the invasion of the alien hyacinth. It could sustain a much more significant wildlife landscape if some of the surrounding areas were restored to suitable habitats. Hence, tourism value is currently limited – centered primarily on Rwanda's Akagera National Park. At present, this landscape's most important local benefit appears to be the provision

of natural resources that are typically harvested by poor households, which support subsistence needs and commercial ventures. The estimated value of these services is particularly high considering the small area covered by the wetlands relative to the other landscapes in the study.

To reduce unsustainable resource and land use, policy discussions should focus on the following priorities:

1 Taking a transboundary approach to protecting and ensuring wise use of wetlands

This wetland system plays a significant role in preventing excess nutrient loads from reaching Lake Victoria and in supporting the livelihoods of people who live in and around the landscape in Burundi, Rwanda, and Tanzania. More sustainable wetlands management is needed to combat a range of threats that affect all three countries. This will require a transboundary engagement that harmonizes policies on wise use of wetlands, e.g., categorization of wetlands as protected zones where no infrastructure developments or other wetland-degrading activities are allowed.

In Rwanda, the enactment of Environmental Law No 48/2018 of 13/08/2018, which contains explicit provisions on sustainable wetlands management, was a step in the right direction. But it requires complementary legislation in Burundi and Tanzania. Community involvement and improved awareness of the value of natural capital will be critical to achieving a similar, sustainable policy-level result.

The NBSAPs of all countries propose granting access permits to local communities living adjacent to protected areas for sustainable harvesting and extraction of medicinal plants (CBD, 2020). But due to inadequate regulations and weaknesses in the implementation of existing laws and regulations, wetland conversion and over-harvesting of high-value plant species persist (CBD, 2020). Coordinated improvements in NBSAP implementation, as well as the enforcement of existing laws and policies, is needed.

2 Enhancing nature tourism and diversifying people's livelihoods

One-third of the Lake Victoria Basin population, including those in this landscape, are poor (living on $1.25/day or less (WB, 2016). Poverty is a key driver of unsustainable wetland resource harvesting. Programs that incentivize or facilitate alternative, environment-friendly livelihoods would draw pressure away from nature. The landscape's unique biodiversity, combined with livelihood-focused interventions to support it, have the potential to radically transform the local economy.

Tourism is one possible engine for transformational change. However, while the funding of Akagera National Park has resulted in growth and benefits, the Lacs du Nord protected area and Ibanda-Kyerwa National Park are not meeting their tourism potential due to insufficient funding. Private sector investment and marketing could enable the development of attractive tourism services and products that incentivize wetlands conservation.

Other interventions could focus on the fisheries sector, which is at risk due to eutrophication and invasive alien species. One successful intervention, the World Bank-funded LVEMP established in 2016, is currently in its second phase and offers a potential model. The program has initiated over 600 community-driven development projects that support environment-friendly livelihoods – including stall feeding to reduce dependence on grazing; fish farming to reduce pressure on Lake Victoria wild fisheries; and using biogas to lower dependence on fuel wood. To date, the project has supported more than 200,000 people (WB, 2016).

3 Controlling invasive alien species

Controlling invasive alien species and their impacts is a major challenge, particularly the water hyacinth (*Eichhornia crassipes*), a noxious aquatic weed that deprives the waters below of oxygen and affects brooders and juveniles of tilapia, a key fisheries species. This weed also creates numerous hazards for local residents. In Rwanda, the species has driven Lake

Kishanju to evaporate to the point of a wetland, along with the fisheries-based livelihoods it supported (REMA, 2016). Water hyacinth continues to spread to other water bodies with ease, affecting biodiversity and livelihoods and necessitating urgent control and eradication measures.

Downstream in Lake Victoria, the weed has had a multitude of direct and indirect effects on many aspects of human life following its invasion in 1989, including on fisheries (impairing fishing, breeding, and nursery grounds), water supply, hydroelectric power generation, human health, agriculture, transport, aquatic biodiversity, evapotranspiration, and increased cost of water treatment (Makhanu, 1997). As a regional problem, the EAC Partner States need a joint approach to its management.

KEY STAKEHOLDER GROUPS

Stakeholder group	Call to action	Benefits to stakeholder
Smallholder farmers, cattle keepers, fishers, and handicraft artisans	• Promote sustainable extraction and rehabilitation of natural resources, including lucrative medicinal plants • Address bush burning in Tanzania • Clear alien invasive species and rehabilitate degraded areas	Continued sustainability of livelihoods and natural resource based income-generating activities
Energy sector and national water supply agencies	Advocate for continued upstream management to preserve downstream flow	Continued profitability and power generation capability using existing infrastructure
National water supply agencies	Support PES for clean water and reduced water hyacinth invasion	Continued availability of water to clients
Tourism sector	• Continue investing in Akagera National Park as a Big Five destination • Invest more in tourism for the other two protected areas, including pursuing private sector investment in new offerings • Reinvestment of profits into wildlife conservation	Increased opportunities for revenue, as well as broadening and stabilizing of the market
Fisheries sector	• Within landscape – practice sustainable fishing and address water hyacinth removal • Downstream (in Lake Victoria) – support PES for controlling eutrophication and invasive water hyacinth	Increased catches of key fisheries species and sustainable income
Community groups	• Identify community priorities for sustainable use of resources and participate in development of management plans for the wetlands • Capitalizing on gorilla tourism, participate in CBNRM and community-based tourism endeavors to restore additional areas around the current wetlands to wilderness status	Sustainable access to natural resources like papyrus and other key wildlife products, as well as more livelihood opportunities or jobs
National and regional policymakers	• Harmonize policies across borders on wise use of wetlands and controlling invasive species • Improve enforcement • Support environment-friendly livelihoods	Support for integrated water resources management, as well as the process driven by the Lake Victoria Basin Commission
International development partners and NGOs	Support local and regional agendas	Conservation of biodiversity and carbon storage

Elephants, Kenya

PHOTO: BEMYSOLUTION

Silhouette of a lion against the African sunset

PHOTO: EO

V. NEXT STEPS

The value of these four iconic landscapes is indisputable. It lies not just in their intrinsic beauty and cultural significance, but, as this synthesis shows, in the services their ecosystems provide to support economic and human well-being across the region. However, the threats to natural capital in East Africa are significant. In addition to population growth placing ever-increasing pressure on resources, climate change stands to exacerbate environmental and economic challenges on an unprecedented scale.

There are many stakeholders who benefit from and steward natural capital in this region. They share a mutual dependence on preserving the ecosystems that underpin all aspects of life, and therefore need to unite around shared solutions to conservation and sustainable development. That's why this study was conducted at the landscape level. Because upstream actions have downstream consequences, and the interests of each country, sector, community, and species are intimately connected.

A transboundary approach is critical to ensuring conservation of East Africa's natural capital. The team has already convened hundreds of stakeholders at the landscape, national, and regional levels to review and validate the data, as well as develop a draft action plan. The draft plan emphasizes the importance of prioritizing nature-based solutions, which the UN's International Union for the Conservation of Nature defines as: "actions to protect, sustainably manage, and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits." In other words, decision makers in both the public and private sectors should work together to invest in healthy ecosystems that provide benefits to people, business, and nature. Under the guidance of the East African Community and Partner States, the action plan will be finalized by early 2022.

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PHOTO: GUDKOVANDREY

Close up of an African lion

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Appendix B1. Mammals of NNP

According to Vande weghe & Vande weghe, in prep.

Habitat: F= forest ; N=non forest ; NF= non forest-forest ; Aq= aquatic.
Biogeography: AR= Albertine Rift endemic; ar= Albertine Rift subendemic.; Int= introduced.
IUCN status: CR= critically endangered ; E= endangered ; VU= vulnerable.
Nyungwe/Cyamudongo: ☐= présent; ☒= extinct locally.

	Habitat	Biogeography	IUCN Status	Nyungwe	Cyamudongo
PROCAVIIDAE					
Western Tree Hyrax, *Dendrohyrax arboreus*	F			☐	☐
ELEPHANTIDAE					
Savanna Elephant, *Loxodonta africanus*	FN		EN	☒	
CHRYSOCHLORIDAE					
Stuhlmann's Golden Mole, *Chrysochloris stuhlmanni*	FN			☐	
TENRECIDAE					
Ruwenzori Otter Shrew, *Micropotamogale ruwenzorii*	Aq	AR		☐	
SCIURIDAE					
Carruthers's Mountain Squirrel, *Funisciurus carruthersi*	F	AR		☐	
Fire-footed Rope Squirrel, *Funisciurus pyrropus*	F			☐	
Red-legged Sun Squirrel, *Heliosciurus rufobrachium*	F			☐	
Ruwenzori Sun Squirrel, *Heliosciurus ruwenzorii*	F	AR		☐	
Boehm's Squirrel. *Paraxerus boehmi*	F			☐	
African Giant Squirrel, *Protoxerus stangeri*	F			☐	
ANOMALURIDAE					
Lord Derby's Anomalure, *Anomalurus derbianus*	F			☐	
GLIRIDAE					
Forest Dormouse, *Graphiurus murinus*	F			☐	
SPALACIDAE					
Rwanda Mole-Rat, *Tachyoryctes splendens*	FN			☐	
NESOMYIDAE					
Kivu Giant Rat, *Cricetomys "kivuensis"*	FN			☐	
Delany's Swamp Mouse, *Delanymys brooksi*	N	AR	Vu	☐	
Montane Afric. Climbing Mouse, *Dendromus insignis*	N			☐	
Kivu Climbing Mouse, *Dendromus nyassae*	FN	AR		☐	
Tiny African Fat Mouse, *Steatomys parvus*	N			☐	
MURIDAE					
African Wading Rat, *Colomys goslingi*	FN			☐	
Rwandan Marsh Rat, *Dasymys rwandae*	?	Rw		☐	
Peters's Striped Mouse, *Hybomys univittatus*	F			☐	
Stella Wood Mouse, *Hylomyscus stella*	F			☐	
Montane Wood Mouse, *Hylomycus vulcanorum*	F	AR		☐	
Zebra Mouse, *Lemniscomyscus striatus*	N			☐	
Big-eared Swamp Rat, *Malacomys longipes*	F			☐	
Toad Mouse, *Mus bufo*	F	AR		☐	
African Pygmy Mouse, *Mus musculoides*	FN			☐	
Grey-bellied Pygmy Mouse, *Mus triton*	FN			☐	
Rusty-nosed Rat, *Oenomys hypoxanthus*	N			☐	
Hopkin's Groove-toothed Swamp Rat, *Pelomys hopkinsi*	Aq	ar		☐	
De Graaff's Soft-furred M., *Praomys degraaffi*	F	AR	Vu	☐	
Jackson's Soft-furred Mouse, *Praomys jacksoni*	F			☐	
Roof Rat, *Rattus rattus*	N	Int		☐	
Kemp's Thicket Rat, *Thamnomys kempi*	F	AR	Vu	☐	
Dent's Vlei Rat, *Otomys denti*	N			☐	
East African Vlei Rat, *Otomys tropicalis*	N			☐	
Link Rat, *Deomys ferrugineus*	F			☐	
Dark-coloured Brush-furred Rat, *Lophuromys aquilus*	?			☐	
Buff-bellied Brush-furred Rat, *Lophuromys luteogaster*	?			☐	

	Habitat	Biogeography	IUCN Status	Nyungwe	Cyamudongo
Western Rift Brush-furred Rat, *Lophuromys medicaudatus*	F	AR	Vu	☐	
Rahm's Brush-furred Rat, *Lophuromys rahmi*	F	AR	NT	☐	
Woosnam's Brush-furred Rat, *Lophuromys woosnami*	F	AR		☐	
HYSTRICIDAE					
Athérure, *Atherurus africanus*	F			☐	
THRYONOMYIDAE					
Marsh Cane-Rat, *Thryonomys swinderianus*	N			☐	
LORISIDAE					
Eastern Potto, *Perodicticus ibeanus*	F			☐	
GALAGIDAE					
Spectacled Galago, *Galago matschei*	F	ar		☐	☐
Thomas Galago, *Galagoides thomasi*	FN			☐	
CERCOPITHECIDAE					
Red-tailed Monkey, *Cercopithecus ascanius*	F			☐	
Dent's Monkey , *Cercopithecus denti*	F			☐	
Blue Monkey, *Cercopithecus doggetti*	F			☐	☐
Owl-faced Monkey, *Cercopithecus hamlyni*	F	ar	Vu	☐	
Golden Monkey, *Cercopithecus (mitis) kandti*	F	AR	En	☐	
L'Hoest's Monkey, *Allochrocebus lhoesti*	F	ar	Vu	☐	
Vervet Monkey, *Chlorocebus pyrgerythrus*	N			☐	
Johnston's Mangabey, *Lophocebus johnstoni*	F			☐	
Olive Baboon, *Papio anubis*	N			☐	☐
Angola Colobus, *Colobus angolensis*	F		Vu	☐	
HOMINIDAE					
Common Chimpanze, *Pan troglodytes*	F		En	☐	☐
SORICIDAE					
Hildegarde's Shrew, *Crocidura hildegardae*	FN			☐	
Kivu Long-haired Shrew, *Crocidura lanosa*	F	AR	Vu	☐	
Swamp Shrew, *Crocidura maurisca*	Aq			☐	
African Black Shrew, *Crocidura nigrofusca*	F			☐	
African Giant Shrew, *Crocidura olivieri*	FN			☐	
Greater Large-headed Sh., *Paracrocidura maxima*	F			☐	
Ruwenzori Shrew, *Ruwenzorisorex suncoides*	F	AR	Vu	☐	
Armoured Shrew, *Scutisorex somerini*	F	ar		☐	
Grant's Forest Shrew, *Sylvisorex granti*	F	ar		☐	
Volcano Shrew, *Sylvisorex vulcanorum*	F	AR		☐	
Moon Forest Shrew, *Sylvisorex lunaris*	F	AR		☐	
SUIDAE					
Giant Forest Hog, *Hylochoerus meinertzhageni*	FN			☒	
Bush Pig, *Potamochoerus larvatus*	FN			☐	
BOVIDAE					
Cape Buffalo, *Syncerus caffer*	FN			☒	
Bushbuck, *Tragelaphus scriptus*	N			☐	
Lestrade's Duiker, *Cephalophus weynsii lestradei*	F	AR		☐	
Black-fronted Duiker, *Cephalophus nigrifrons*	F			☐	
Yellow-backed Duiker, *Cephalophus silvicultor*	F			☐	
PTEROPODIDAE					
African Straw-coloured Fruit Bat, *Eidolon helvum*	FN			☐	
Minor Epauletted Fruit Bat, *Epomophorus labiatus*	N			☐	
Wahlberg's Epauletted Fruit Bat, *Epomops wahlbergi*	N			☐	
Angolan Soft-Furred Fruit Bat, *Lissonycteris angolensis*	FN			☐	
Egyptian Rousette, *Rousettus aegyptiacus*	FN			☐	
Long-haired Rousette, *Stenonycteris lanosus*	F			☐	
NYCTERIDAE					
Bate's Slit-faced Bat, *Nycteris arge*	FN			☐	
Hairy Slit-faced Bat, *Nycteris hispida*	FN			☐	
Large-eared Slit-faced Bat, *Nycteris macrotis*	FN			☐	
Dwarf Slit-faced Bat, *Nycteris nana*	FN			☐	
Cape Long-eared Bat, *Nycteris thebaica*	FN			☐	

	Habitat	Biogeography	IUCN Status	Nyungwe	Cyamudongo
RHINOLOPHIDAE					
Eloquent Horseshoe Bat, *Rhinolophus eloquens*	FN				☐
Hill's Horseshoe Bat, *Rhinolophus hilli*	F	Rw	Cr	☐	
HIPPOSIDERIDAE					
Sundevall's Leaf-nosed Bat, *Hyposideros caffer*	N			☐	
MOLOSSIDAE					
Little Free-tailed Bat, *Chaerephon pumilus*	FN				☐
VESPERTILIONIDAE					
Greater Long-fingered Bat, *Miniopterus inflatus*	FN			☐	
Welwitsch's Mouse-eared Bat, *Myotis welwitschii*	N			☐	
Eisentraut's Pipistrelle, *Hypsugo eisentrauti*	F			☐	
Lesser Wolly Bat, *Kerivoula lanosa*	FN			☐	
Cape Bat, *Neoromicia capensis*	FN			☐	
Banana Pipistrelle, *Neoromicia nana*	FN			☐	☐
Dusky Pipistrelle, *Pipistrellus hesperidus*	N			☐	
MANIDAE					
White-bellied Pangolin, *Phataginus tricuspis*	F			☐	
FELIDAE					
African Wildcat, *Felis sylvestris*	N			☐	
Serval, *Leptailurus serval*	FN			☐	
Golden Cat, *Caracal aurata*	F		Vu	☐	
Leopard, *Panthera pardus*	FN		Vu	☒	☒
VIVERRIDAE					
African Civet, *Civettictis civetta*	N			☐	☐
Large-spotted Genet, *Genetta maculata*	N			☐	
Small-spotted Genet, *Genetta servalina*	F			☐	
Giant Genet, *Genetta victoriae*	F	ar		☐	
African Linsang, *Poiana richardsoni*	F				
NANDINIIDAE					
African Palm Civet, *Nandinia binotata*	F			☐	
HERPESTIDAE					
Marsh Mongoose, *Atilax paludinosus*	FN			☐	☐
Red Mongoose, *Galerella sanguinea*	FN			☐	☐
Egyptian Mongoose, *Herpestes ichneumon*	N			☐	
CANIDAE					
Side-striped Jackal, *Lupulella adusta*	N			☐	
MUSTELLIDAE					
Swamp Otter, *Aonyx congica*	Aq			☐	
Striped Weasel, *Poecilogale albinucha*	N			☐	

Appendix B2. Birds of Nyungwe National Park

According to G.R. Vande weghe (2021)

Status in Rwanda : RB= resident, breeding ; R= resident, breeding not confirmed ; M= Afro-tropical migrant ; Mp= Palearctic migrant ; Mm= Malagassy migrant.
Frequency : Irr= irregularly seen ; Occ= occasional ; Ext/x = locally extinct.
Biogeography: AR= Albertine Rift endemic; ar= Albertine Rift subendemic.
Habitat : F= forest ; N non forest ; NF= non forest-forest ; A= aquatic ; R= Rocks ; O= overhead aerial screener.
IUCN status : CR= critically endangered ; E= endangered ; VU= vulnerable.
Nyungwe/Cyamudongo: ☐= présent; ☒= extinct locally.

	Status	Frequancy	Blogéographie	Habitat	IUCN Status	Nyungwe	Cyamudongo
NUMIDIDAE							
Helmeted Guineafowl, *Numida meleagris*	St	Occ		N		☐	
PHASIANIDAE							
Red-winged Francolin, *Scleroptila vaillantii*	RB			N		☐	
Scaly Francolin, *Pternistis squamatus*	RB			NF		☐	☐
Handsome Francolin, *Pternistis nobilis*	RB		AR	F		☐	
Common Quail, *Coturnix coturnix*	RB			N		☐	
ANATIDAE							
Hartlaub's Duck, *Pteronetta hartlaubii* [2]	St	Occ		A		☐	
African Black Duck, *Anas sparsa*	RB			A		☐	
Yellow-billed Duck, *Anas undulata*	RB			A		☐	
Red-billed Teal, *Anas erythrorhyncha*	RB			A		☐	
PODICIPEDIDAE							
Little Grebe, *Tachybaptus ruficollis*	RB			A		☐	
CICONIIDAE							
Yellow-billed Stork, *Mycteria ibis*	RB			A		☐	
White Stork, *Ciconia ciconia*	Mp	Irr		N		☐	
THRESKIORNITIDAE							
Hadada Ibis, *Bostrychia hagedash*	RB			A		☐	
African Sacred Ibis Threskiornis aethiopicus	M					☐	
ARDEIDAE							
Black-crowned Night H., *Nycticorax nycticorax*	RB			A		☐	
Striated Heron, *Butorides striata*	RB			A		☐	
Western Cattle Egret, *Bubulcus ibis*	R			NA		☐	☐
Grey Heron Ardea cinerea	R			A		☐	
Black-headed Heron, *Ardea melanocephala*	RB			NA			☐
Goliath Heron, *Ardea goliath*	RB			A			☐
Purple Heron, *Ardea purpurea*	RB			A		☐	☐
Western Great Egret, *Casmerodius albus*	RB			A		☐	☐
SCOPIDAE							
Hamerkop, *Scopus umbretta*	RB			A			☐
ACCIPITRIDAE							
Black-winged Kite, *Elanus caeruleus*	RB			N		☐	
African Harrier-Hawk, *Polyboroides typus*	RB			NF		☐	☐
European Honey Buzzard, *Pernis apivorus*	Mp			F		☐	☐
African Cuckoo-Hawk, *Aviceda cuculoides*	M			FN		☐	
Palm-nut Vulture, *Gypohierax angolensis*	RB			N		☐	
White-headed Vulture, *Trigonoceps occipitalis*	RB			N	CR	☒	
Hooded Vulture, *Necrosytes monachus*	RB			N		☐	
Brown Snake Eagle, *Circaetus cinereus*	RB			N		☐	
Bateleur, *Terathopius ecaudatus*	RB			N	NT	☐	
Bat Hawk, *Macheiramphus alcinus*	RB			NF		☐	
Cassin's Hawk-Eagle, *Aquila africana*	RB			F		☐	
Tawny Eagle, *Aquila rapax*	RB			N		☐	
Verreaux's Eagle, *Aquila verreauxii*		Occ		N		☐	
Wahlberg's Eagle, *Hieraaetus wahlbergi*	MB			N		☐	

	Status	Frequancy	Biogéographie	Habitat	IUCN Status	Nyungwe	Cyamudongo
Long-crested Eagle, *Lophaetus occipitalis*	RB			N		☐	
Martial Eagle, *Polemaetus bellicosus*	RB			N	V	☒	
Crowned Eagle, *Stephanoaetus coronatus*	RB			F		☐	
Yellow-billed Kite, *Milvus aegyptius*	RB			N		☐	☐
Augur Buzzard, *Buteo augur*	RB			N		☐	☐
Common Buzzard, *Buteo buteo*	Mp			N		☐	☐
Mountain Buzzard, *Buteo oreophilus*	RB			F		☐	
Western Marsh Harrier, *Circus aeruginosus*	Mp			A		☐	
African Goshawk, *Accipiter tachiro*	RB			NF		☐	☐
Great Sparrowhawk, *Accipiter melanoleucus*	RB			NF		☐	
Little Sparrowhawk, *Accipiter minullus*	RB			N		☐	
Red-thighed Sparrowhawk, *Accipiter erythropus*		Occ		F			☐
Rufous-breasted Sparrowhawk, *Accipiter rufiventris*	RB			N		☐	☐
GRUIDAE							
Grey Crowned Crane, *Balearica regulorum*	RB			A	EN	☐	
SAROTHRURIDAE							
White-spotted Flufftail, *Sarothrura pulchra*	RB			F		☐	
Buff-spotted Flufftail, *Sarothrura elegans*	RB			FAq		☐	
Red-chested Flufftail, *Sarothrura rufa*	RB			A		☐	
RALLIDAE							
African Water Rail, *Rallus caerulescens*	R			A		☐	
Black Crake, *Limnocorax flavirostra*	RB			A		☐	
TURNICIDAE							
Common Buttonquail, *Turnix sylvaticus*	RB			N		☐	
SCOLOPACIDAE							
Common Sandpiper, *Actitis hypoleucos*	Mp			A		☐	
Green Sandpiper, *Tringa ochropus*	Mp			A		☐	
Wood Sandpiper, *Tringa glareola*	Mp			A		☐	
African Snipe, *Gallinago nigripennis*	R			A		☐	
Common Snipe, *Gallinago gallinago*	Mp			A		☐	
COLUMBIDAE							
Afep Pigeon, *Columba unicincta*		Irr		F		☐	
African Olive Pigeon, *Columba arquatrix*	RB			F		☐	
Lemon Dove, *Columba larvata*	RB			F		☐	
Dusky Turtle Dove, *Streptopelia lugens*	RB			F		☐	
Red-eyed Dove, *Streptopelia semitorquata*	RB			N		☐	☐
Blue-spotted Wood-Dove, *Turtur afer*	RB			N		☐	☐
Tambourine Dove, *Turtur tympanistria*	RB			F		☐	☐
African Green Pigeon, *Treron calvus*	RB			NF		☐	☐
MUSOPHAGIDAE							
Great Blue Turaco, *Corythaeola cristata*	RB			F		☐	☐
Kivu Turaco, *Gallirex johnstoni (johnstoni) kivuensis*	RB			F		☐	
Ross's Turaco, *Musophaga rossae*	RB			NF		☐	☐
Eastern Black-billed Turaco, *Tauraco eminii*	RB			F		☐	☐
CUCULIDAE							
Blue-headed Coucal, *Centropus monachus*	RB			N		☐	☐
White-browed Coucal, *Centropus superciliosus*	RB			N		☐	
Blue Malkoha, *Ceuthmochares aereus*	RB			F		☐	☐
Levaillant's Cuckoo, *Clamator levaillantii*	MB			N		☐	
Dideric Cuckoo, *Chrysococcyx caprius*	RB			N		☐	☐
Klaas's Cuckoo, *Chrysococcyx klaas*	RB			N		☐	☐
African Esmerald Cuckoo, *Chrysococcyx cupreus*	RB			F		☐	☐
Barred Long-tailed Cuckoo, *Cercococcyx montanus*	RB			F		☐	
Black Cuckoo, *Cuculus clamosus*	MB			F		☐	☐
Red-chested Cuckoo, *Cuculus solitarius*	MB			NF		☐	☐
Common Cuckoo, *Cuculus canorus*	Mp			N		☐	☐
TYTONIDAE							
Western Barn Owl, *Tyto alba*	RB			NF		☐	
African Grass Owl, *Tyto capensis*	RB			NA		☐	

	Status	Frequancy	Biogéographie	Habitat	IUCN Status	Nyungwe	Cyamudongo
Congo Bay Owl, *Tyto prigoginei (Phodilus prigoginei)*	?		AR	F	EN	☐	
STRIGIDAE							
Spotted Eagle-Owl, *Bubo africanus*	RB			N		☐	
Fraser's Eagle-Owl, *Bubo poensis*	RB			F		☐	
Verreaux's Eagle-Owl, *Bubo lacteus*	RB			N		☐	
African Wood Owl, Strix woodfordii	RB			F		☐	☐
Red-chested Owlet, *Glaucidium tephronotum*	RB			F		☐	
Albertine Owlet, *Glaucidium albertinum*	R		AR	F	V	☐	
Abyssinian Owl, *Asio graueri*	R		AR	F		☐	
CAPRIMULGIDAE							
Fiery-necked Nightjar, *Caprimulgus pectoralis*	?			N		☐	
Ruwenzori Nightjar, *Caprimulgus ruwenzorii*	RB		AR	F		☐	
Square-tailed Nightjar, *Caprimulgus fossii*	RB			N		☐	
Pennant-winged Nj., *Macrodipteryx vexillarius*	M			N		☐	
APODIDAE							
African Palm Swift, *Cypsiurus parvus*	R						
Scarce Swift, *Schoutedenapus myoptilus*	R			OF		☐	
Common Swift, *Apus apus*	Mp			O		☐	☐
Little Swift, *Apus affinis*	RB			O		☐	
Horus Swift, *Apus horus*	RB			O		☐	
White-rumped Swift, *Apus caffer*	RB			O		☐	
COLIIDAE							
Speckled Mousebird, *Colius striatus*	RB			N		☐	☐
TROGONIDAE							
Narina Trogon, *Apaloderma narina*	RB			NF		☐	☐
Bar-tailed Trogon, *Apaloderma vittatum*	RB			F		☐	☐
CORACIIDAE							
Lilac-breasted Roller, *Coracias caudatus*	RB			N		☐	
Broad-billed Roller, *Eurystomus glaucurus*	M			N		☐	
ALCEDINIDAE							
African Pygmy Kingfisher, *Ispidina picta*	RB			NF		☐	
Shining-blue Kingfisher, *Alcedo quadribrachys*	RB			A		☒	
Malachite Kingfisher, *Corythornis cristatus*	R			A			
Grey-headed Kingfisher Halcyon leucocephala	M			N			
Woodland Kingfisher, *Halcyon senegalensis*	RB			N		☐	
MEROPIDAE							
Cinnamon-chested Bee-eater, *Merops oreobates*	RB			F		☐	☐
White-throated Bee-eater, *Merops albicollis*	M	Irr		FN			
European Bee-eater, *Merops apiaster*	Mp			N		☐	☐
PHOENICULIDAE							
Forest Wood Hoopoe, *Phoeniculus castaneiceps*	R			F		☐	
White-headed Wood Hoopoe, *Phoeniculus bollei*	RB			F		☐	☐
Green Wood Hoopoe, *Phoeniculus purpureus*	RB			N		☐	
UPUPIDAE							
African Hoopoe, *Upupa africana*	M			N			
BUCEROTIDAE							
Crowned Hornbill, *Lophocerus alboterminatus*	RB			NF		☐	☐
Black-and-white-casqued Hornbill, *Bycanistes subcylindricus*	RB			F		☐	
LYBIIDAE							
Grey-throated Barbet, *Gymnobucco cinereiceps*	RB			F		☐	☐
Western Tinkerbird, *Pogoniulus coryphaeus*	RB			F		☐	
Yellow-rumped Tinkerbird, *Pogoniulus bilineatus*	RB			NF		☐	☐
Double-toothed Barbet, *Pogonornis bidentatus*	R			NF			
Yellow-billed Barbet, *Trachyphonus purpuratus*	R?			F		☐	
INDICATORIDAE							
Green-backed Honeybird, *Prodotiscus zambesiae*	M	Oc		F		☐	
Dwarf Honeyguide, *Indicator pumilio*	R			F		☐	
Willcocks's Honeyguide, *Indicator willcocksi*	R			F		☐	
Least Honeyguide, *Indicator exilis*	RB			F		☐	

	Status	Frequancy	Biogéographie	Habitat	IUCN Status	Nyungwe	Cyamudongo
Lesser Honeyguide, *Indicator minor*	RB			N		☐	
Scaly-throated Honeyguide, *Indicator variegatus*	RB			F		☐	
Greater Honeyguide, *Indicator indicator*	RB			N		☐	
PICIDAE							
Fine-banded Woodpecker, *Campethera taeniolaema*	RB			F		☐	
Eastern Buff-spotted Woodpecker, *Stictopicus herberti*	R			F		☐	
Cardinal Woodpecker, *Dendropicos fuscescens*	RB			NF		☐	☐
Elliot's Woodpecker, *Dendropicos elliotii*	RB			F		☐	
Olive Woodpecker, *Dendropicos griseocephalus*	RB			F		☐	☐
FALCONIDAE							
Common Kestrel, *Falco rufescens*	RB			R		☐	
African Hobby, *Falco cuvierii*		Irr		N			
Eurasian Hobby, *Falco subbuteo*	Mp			N		☐	☐
Lanner Falcon, *Falco biarmicus*	RB			N		☐	
Peregrine Falcon, *Falco peregrinus*	RB			R		☐	
PSITTACIDAE							
Grey Parrot, *Psittacus erithacus*	RB			F	V	☐	☒
Cape Parrot, *Poicephalus fuscicollis* *	RB			F		☐	
SMITHORNITIDAE							
African Broadbill, *Smithornis capensis*	RB			F		☐	
PLATYSTEIRIDAE							
Ruwenzori Batis, *Batis diops*	RB		AR	F		☐	☐
Chinspot Batis, *Batis molitor*	RB			NF		☐	☐
Brown-throated Wattle-eye, *Platysteira cyanea*	RB			N		☐	☐
Black-throated Wattle-eye, *Platysteira peltata*		Occ		N		☐	
Yellow-bellied Wattle-eye, *Platysteira concreta*	RB			F		☐	
MALACONOTIDAE							
Lagden's Bushshrike, *Malaconotus lagdeni*	RB			F		☐	
Many-coloured Bshr., *Chlorophoneus multicolor*	RB			F		☐	☐
Doherty's Bushshrike, *Telophorus dohertyi*	RB			F		☐	☐
Brown-crowned Tchagra, *Tchagra australis*	RB			N		☐	☐
Black-crowned Tchagra, *Tchagra senegalus*	R?	Occ		N			
Pink-footed Puffback, *Dryoscopus angolensis*	RB			F		☐	
Red-eyed Puffback, *Dryoscopus senegalensis*	RB			F		☐	
Northern Puffback, *Dryoscopus gambensis*	RB			F		☐	☐
Mountain Sooty Boubou, *Laniarius holomelas*	RB			F		☐	
Willard's Sooty Boubou, *Laniarius willardii*	RB		AR	F		☐	
Lühder's Bushshrike, *Laniarius luehderi*	RB			F		☐	☐
Tropical Boubou, *Laniarius major*	RB			N		☐	☐
CAMPEPHAGIDAE							
Grey Cuckooshrike, *Ceblepyris caesius*	RB			F		☐	
Black Cuckooshrike, *Campephaga flava*	MB			N		☐	☐
Petit's Cuckooshrike, *Campephaga petiti*	RB			F		☐	
LANIIDAE							
Red-backed Shrike, *Lanius collurio*	Mp			N		☐	
Northern Fiscal, *Lanius humeralis*		Occ		N			
Mackinnon's Shrike, *Lanius mackinnoni*	RB			N		☐	☐
ORIOLIDAE							
Eurasian Golden Oriole, *Oriolus oriolus*	Mp			N		☐	
African Golden Oriole, *Oriolus auratus*	M			N		☐	
Mountain Oriole, *Oriolus percivali*	RB			F		☐	☐
DICRURIDAE							
Velvet-mantled Drongo, *Edolius modestus*	RB			F		☐	☐
MONARCHIDAE							
Blue-mantled Crested Flycatcher, *Trochocercus cyanomelas*	RB			F		☐	☐
African Paradise Flycatcher, *Terpsiphone viridis*	RB			NF		☐	☐
CORVIDAE							
Pied Crow, *Corvus albus*	RB			N		☐	
White-necked Raven, *Corvus albicollis*	RB			NF		☐	

	Status	Frequancy	Biogéographie	Habitat	IUCN Status	Nyungwe	Cyamudongo
HYLIOTIDAE							
Violet-backed Hyliota, *Hyliota violacea*	RB			F		☐	
STENOSTIRIDAE							
White-tailed Blue Flycatcher, *Elminia albicauda*	RB			F		☐	
White-bellied Crested Flycatcher, *Elminia albiventris*	RB			F		☐	
White-tailed Crested Flycatcher, *Elminia albonotata*	RB			N		☐	
PARIDAE							
White-winged Black Tit, *Melaniparus leucomelas*	RB			N		☐	
Dusky Tit, *Melaniparus funereus*	RB			F		☐	
Stripe-breasted Tit, *Melaniparus fasciiventer*	RB		AR	F		☐	☐
ALAUDIDAE							
Dusky Lark, *Pinarocorys nigricans*		Occ					
PYCNONOTIDAE							
Dark-capped Bulbul, *Pycnonotus tricolor*	RB			N		☐	☐
Kakamega Greenbul, *Arizelocichla kakamegae*	RB			F		☐	
Olive-breasted Greenbul, *Arizelocichla kikuyuensis*	RB			F		☐	
Slender-billed Greenbul, *Stelgidillas gracilirostris*	RB			F		☐	☐
Little Greenbul, *Eurillas virens*	RB			F		☐	
Plain Greenbul, *Eurillas curvirostris*	RB			F		☐	
Yellow-whiskered Greenbul, *Eurillas latirostris*	RB			F		☐	☐
Yellow-throated Leaflove, *Atimastillas flavicollis*	RB			N		☐	☐
Cabanis's Greenbul, *Phyllastrephus cabanisi*	RB			F		☐	☐
Yellow-streaked Greenbul, *Phyllastrephus flavostriatus*	RB			F		☐	
HIRUNDINIDAE							
White-headed Saw-wing, *Psalidoprocne albiceps*	RB			N		☐	
Black Saw-wing, *Psalidoprocne pristoptera*	RB			F		☐	☐
Brown-throated Martin, *Riparia paludicola*	RB			N		☐	
Sand Martin, *Riparia riparia*	Mp			N		☐	☐
Barn Swallow, *Hirundo rustica*	Mp			N		☐	☐
Angola Swallow, *Hirundo angolensis*	RB			N		☐	☐
Common House Martin, *Delichon urbicum*	Mp			O		☐	
Lesser Striped Swallow, *Cecropis abyssinica*	RB			N		☐	
Mosque Swallow, *Cecropis senegalensis*	MB			N		☐	
Red-rumped Swallow, *Cecropis daurica*	RB			N		☐	
MACROSPHENIDAE							
Grauer's Warbler, *Graueria vittata*	Rb		AR	F		☐	
White-browed Crombec, *Sylvietta leucophrys*	RB			F		☐	☐
CETTIIDAE							
Neumann's Warbler, *Hemitesia neumanni*	RB		AR	F		☐	
PHYLLOSCOPIDAE							
Willow Warbler, *Phylloscopus trochilus*	Mp			N		☐	☐
Wood Warbler, *Phylloscopus sibilatrix*	Mp			N		☐	
Red-faced Woodland Warbler, *Seicercus laetus*	RB		AR	F		☐	
Brown Woodland Warbler, *Seicercus umbrovirens*	RB			F		☐	
ACROCEPHALIDAE							
Dark-capped Yellow Warbler, *Iduna natalensis*	RB			N		☐	
Mountain Yellow Warbler, *Iduna similis*	RB			F		☐	
Sedge Warbler, *Titiza schoenobaenus*	Mp			A		☐	
Eurasian Reed Warbler, *Notiocichla scirpacea*	Mp			N		☐	
LOCUSTELLIDAE							
Little Rush Warbler, *Bradypterus centralis*	RB			A		☐	
Grauer's Swamp Warbler, *Bradypterus graueri*	RB			A		☐	
Evergreen Forest Warbler, *Bradypterus lopezi*	RB			F		☐	
Cinnamon Bracken Warbler, *Bradypterus cinnamomeus*	RB			F		☐	
CISTICOLIDAE							
Chubb's Cisticola, *Cisticola chubbi*	RB			F		☐	☐
Short-winged Cisticola, *Cisticola brachypterus*	RB			N		☐	
Wing-snapping Cisticola, *Cisticola ayresii*	RB			N		☐	
Tawny-flanked Prinia, *Prinia subflava*	RB			N		☐	

	Status	Frequancy	Biogéographie	Habitat	IUCN Status	Nyungwe	Cyamudongo
Banded Prinia, *Prinia bairdii*	RB			F		☐	
White-chinned Prinia, *Schistolais leucopogon*	RB			NF		☐	☐
Ruwenzori Apalis, *Oreolais ruwenzorii*	RB			F		☐	☐
Mountain Masked Apalis, *Apalis personata*	RB			F		☐	☐
Black-throated Apalis, *Apalis jacksoni*	RB			F		☐	☐
Chestnut-throated Apalis, *Apalis porphyrolaema*	RB			F		☐	☐
Kungwe Apalis, *Apalis argentea*	RB			F		☐	☐
Grey Apalis, *Apalis cinerea*	RB			F		☐	☐
Grey-capped Warbler, *Eminia lepida*	RB			N		☐	☐
Grey-backed Camaroptera, *Camaroptera brevicaudata*	RB			N		☐	☐
Olive-Green Camaroptera, *Camaroptera chloronota*	RB			F		☐	
Black-faced Rufous Warbler, *Bathmocercus rufus*	RB			F		☐	
SYLVIIDAE							
Eurasian Blackcap, *Sylvia atricapilla*	Mp			N		☐	
Garden Warbler, *Sylvia borin*	Mp			N		☐	☐
Ruwenzori Hill Babbler, *Sylvia atriceps*	RB			F		☐	☐
ZOSTEROPIDAE							
African Yellow White-eye, *Zosterops stuhlmanni*	RB			F		☐	☐
PELLORNEIDAE							
Brown Illadopsis, *Illadopsis fulvescens*	RB			F		☐	
Mountain Illadopsis, *Illadopsis pyrrhoptera*	RB			F		☐	☐
LEIOTHRICHIDAE							
Red-collared Babbler, *Phyllanthus rufocinctus*	RB		AR	F		☐	
Arrow-marked Babbler Turdoides jardinei	RB			N			
STURNIDAE							
Violet-backed Starling, *Cinnyricinclus leucogaster*	M			N		☐	
Slender-billed Starling, *Onychognathus tenuirostris*	RB			F		☐	
Waller's Starling, *Onychognatus walleri*	RB			F		☐	
Stuhlmann's Starling, *Poeoptera stuhlmanni*	RB			F		☐	☐
Sharpe's Starling, *Pholia sharpii*	MB			F		☐	☐
TURDIDAE							
White-tailed Rufous Thrush, *Neocossyphus poensis*	RB			F		☐	☐
Kivu Ground Thrush, *Geokichla tanganjicae*	RB		AR	F		☐	
African Thrush, *Turdus pelios*	RB			N		☐	☐
Abyssinian Thrush, *Turdus abyssinicus*	RB			F		☐	
MUSCICAPIDAE							
Brown-backed Scrub Robin, *Cercotrichas hartlaubi*	RB			F		☐	
White-eyed Slaty Flycatcher, *Melaenornis fischeri*	RB			NF		☐	☐
Yellow-eyed Black Flycatcher, *Melaenornis ardesiacus*	RB		AR	F		☐	
Pale Flycatcher Agricola pallidus		Occ					
Grey Tit-Flycatcher, *Fraseria plumbea*	RB			NF		☐	
Ashy Flycatcher, *Fraseria caerulescens*	RB			N		☐	
Spotted Flycatcher, *Muscicapa striata*	Mp			N		☐	☐
Cassin's Flycatcher, *Muscicapa cassini*	RB	?		A		☐	
African Dusky Flycatcher, *Muscicapa adusta*	RB			NF		☐	☐
Cape Robin-Chat, *Dessornornis caffra*	RB			N		☐	
Archer's Ground Robin, *Dessonornis archeri*	RB		AR	F		☐	
White-starred Robin, *Pogonocichla stellata*	RB			F		☐	
White-bellied Robin-Chat, *Cossyphicula roberti*	RB			F		☐	
Red-throated Alethe, *Chamaetylas poliophrys*	RB		AR	F		☐	☐
Brown-chested Alethe, *Pseudalethe poliocephala*	RB			F		☐	☐
White-browed Robin-Chat, *Cossypha heuglini*	RB			N		☐	☐
Red-capped Robin-Chat, *Cossypha natalensis*	M			NF		☐	
Snowy-crowned Robin-Chat, *Cossypha niveicapilla*	RB			F		☐	☐
Eastern Forest Robin, *Stiphrornis xanthogaster*	Ext			F		☐	
Equatorial Akalat, *Sheppardia aequatorialis*	RB			F		☐	☐
Miombo Rock Thrush, *Monticola angolensis*	RB			N		☐	
African Stonechat, *Saxicola torquatus*	RB			N		☐	
Ruaha Chat, *Myrmecocichla collaris*	RB			N		☐	

	Status	Frequancy	Biogéographie	Habitat	IUCN Status	Nyungwe	Cyamudongo
Familiar Chat, *Oenanthe familiaris*	RB			N		☐	
MODULATRICIDAE							
Grey-chested Kakamega, *Kakamega poliothorax*	RB			F		☐	
NECTARINIIDAE							
Little Green Sunbird, *Deleornis seimundi*	RB			F		☐	
Collared Sunbird, *Anthodiaeta collaris*	RB			NF		☐	☐
Green-headed Sunbird, *Cyanomitra verticalis*	RB			N		☐	☐
Blue-throated Brown Sunbird, *Cyanomitra cyanolaema*	RB			F		☐	
Blue-headed Sunbird, *Cyanomitra alinae*	RB		AR	F		☐	
Olive Sunbird, *Cyanomitra olivacea*	RB			F		☐	☐
Scarlet-chested Sunbird, *Chalcomitra senegalensis*	RB			N		☐	☐
Bronzy Sunbird, *Nectarinia kilimensis*	RB			N		☐	☐
Purple-breasted Sunbird, *Nectarinia purpureiventris*	RB		AR	F		☐	
Malachite Sunbird, *Nectarinia famosa*	RB			N		☐	
Ruwenzori Double-collared Sunbird, *Cinnyris stuhlmanni*	RB		AR	F		☐	
Northern Double-collared Sunbird, *Cinnyris reichenowi*	RB			F		☐	☐
Regal Sunbird, *Cinnyris regius*	RB		AR	F		☐	
Olive-bellied Sunbird, *Cinnyris chloropygius*	RB			F		☐	
Rockefeller's Sunbird, *Cinnyris rockefelleri*	RB		AR	F	V	☐	
Variable Sunbird, *Cinnyris venustus*	RB			N		☐	☐
PLOCEIDAE							
Baglafecht Weaver, *Ploceus baglafecht*	RB			N		☐	☐
Spectacled Weaver, *Ploceus ocularis*	RB			N		☐	☐
Black-necked Weaver, *Textor nigricollis*	RB			N		☐	
Strange Weaver, *Ploceus alienus*	RB		AR	F		☐	
Black-billed Weaver, *Ploceus melanogaster*	RB			F		☐	☐
Village Weaver, *Ploceus cucullatus*	RB			N		☐	☐
Vieillot's Black Weaver, *Ploceus nigerrimus*	RB			N		☐	
Dark-backed Weaver, *Ploceus bicolor*	RB			F		☐	
Brown-capped Weaver, *Ploceus insignis*	RB			F		☐	
Holub's Golden Weaver, *Textor xanthops*	RB			N		☐	
Red-billed Quelea, *Quelea quelea*	M			N		☐	
Yellow Bishop, *Euplectes capensis*	RB			N		☐	
Red-collared Widowbird, *Euplectes ardens*	RB			N		☐	
ESTRILDIDAE						☐	
Bronze Mannikin, *Spermestes cucullatus*	RB			N		☐	☐
Black-and-White Mannikin, Spermestes bicolor	RB			N		☐	
Black-chinned Quail-Finch, *Ortygospiza gabonensis*	RB			N		☐	
Red-cheeked Cordon-bleu, *Uraeginthus bengalus*	RB			N		☐	☐
Red-headed Bluebill, *Spermophaga ruficapilla*	RB			N		☐	
Dusky Twinspot, *Euschistospiza cinereovinacea*	RB			N		☐	
Red-billed Firefinch, *Lagonosticta senegala*	RB			N		☐	☐
African Firefinch, *Lagonosticta rubricata*	RB			N		☐	
Grey-headed Nigrita, *Nigrita canicapillus*	RB			F		☐	☐
White-breasted Nigrita, *Nigrita fusconotus*	RB			F		☐	
Yellow-bellied Waxbill, *Coccopygia quartinia*	RB			N		☐	☐
Green Twinspot, *Mandingoa nitidula*	RB			N			☐
Dusky Crimsonwing, *Cryptospiza jacksoni*	RB		AR	F		☐	
Red-faced Crimsonwing, *Cryptospiza reichenovii*	RB			F		☐	
Abyssinian Crimsonwing, *Cryptospiza salvadorii*	RB			F		☐	
Shelley's Crimsonwing, *Cryptospiza shelleyi*	RB		AR	F	EN	☐	
Fawn-breasted Waxbill, *Estrilda paludicola*	RB			N		☐	☐
Common Waxbill, *Estrilda astrild*	RB			N		☐	☐
Crimson-rumped Waxbill, *Estrilda rhodopyga*	?			N		☐	
Black-crowned Waxbill, *Estrilda nonnula*	RB			N		☐	☐
Kandt's Waxbill, *Estrilda kandti*	RB			N		☐	
VIDUIDAE							
Village Indigobird, *Vidua chalybeata*	RB			N		☐	
Pin-tailed Whydah, *Vidua macroura*	RB			N		☐	☐

	Status	Frequancy	Biogéographie	Habitat	IUCN Status	Nyungwe	Cyamudongo
PASSERIDAE							
House Sparrow, *Passer domesticus*	R			N		☐	
Northern Grey-headed Sparrow, *Passer griseus*	RB			N		☐	☐
MOTACILLIDAE							
Western Yellow Wagtail, *Motacilla flava*	Mp			N		☐	
Cape Wagtail, *Motacilla capensis*	RB			N		☐	☐
Grey Wagtail, *Motacilla cinerea*	Mp			N		☐	
Mountain Wagtail, *Motacilla clara*	RB			N		☐	
African Pied Wagtail, *Motacilla aguimp*	RB			N		☐	☐
African Pipit, *Anthus cinnamomeus*	RB			N		☐	
Tree Pipit, *Anthus trivialis*	Mp			FN		☐	
FRINGILLIDAE							
Oriole Finch, *Linurgus olivaceus*	RB			F		☐	
Thick-billed Seedeater, *Crithagra burtoni*	RB			F		☐	☐
Black-throated Seed-eater, *Crithagra atrogularis*	M			N		☐	
Yellow-fronted Canary, *Crithagra mozambica*	R			N		☐	☐
Brimstone Canary, *Crithagra sulphurata*	R			N		☐	☐
Streaky Seedeater, *Crithagra striolata*	RB			FN		☐	☐
Western Citril, *Crithagra frontalis*	RB			N		☐	☐
Yellow-crowned Canary, *Serinus flavivertex*	RB			N		☐	
EMBERIZIDAE							
Golden-breasted Bunting, *Emberiza flaviventris*	RB			N		☐	☐

Appendix B3. Reptiles of Nyungwe National Park

According to J.M. Dehling, E. Fischer, U. Sinch, B. Dumbo, H. Hinkel & H.H. Hinkel (2022)

Habitat: F= forest, N=Non-Forest, FN=forest and non forest.
Biogeography: AR= endemic to the Albertin Rift.
IUCN status: VU= vulnerable, En= endangered, Cr= critically endangered.
Nyungwe/Cyamudongo: ☐= present.

	Habitat	Biogeography	IUCN Status	Nyungwe	Cyamudongo
AGAMIDAE					
Kivu Blue-headed tree agama, *Acanthocercus kiwuensis*	N			☐	☐
CHAMAELEONIDAE					
Flap-necked Chameleon, *Chamaeleo dilepis*	N			☐	
Nyungwe Chameleon, *Kinyonga rugegensis*	F	AR		☐	
Boulenger's Pygmy-Chameleon, *Rhampholeon boulengeri*	F	AR		☐	
Montane Side-striped Chameleon, *Triceros ellioti*	N			☐	
Ruwenzori Three-horned Chameleon, *Triceros johnstoni*	F	AR		☐	
Ruwenzori Side-striped Chameleon, Trioceros rudis	F	AR		☐	
Schouteden's Montane Dwarf Chameleon, *Triceros schoutedeni*	N	AR		☐	
GEKKONIDAE					
Four-lined Forest Gecko, *Cnemaspis quattuorseriatus*	F	AR		☐	
Tropical House Gecko, *Hemidactylus mabouia*	N			☐	
Chevron-throated Dwarf Gecko, *Lygodactylus gutturalis*	N			☐	
LACERTIDAE					
African Forest Lizard, *Adolphus africanus*	N			☐	
Jackson's Forest Lizard, *Adolphus jacksoni*	N	AR		☐	
Sparse-scaled Forest Lizard, *Congolacerta vauereselli*	FN	AR		☐	
Guenther's Forest Lizard, *Holaspis guentheri*	F			☐	
SCINCIDAE					
Congo three-toed Skink, ***Leptosiaphos blochmanni***	F	AR		☐	
Rwanda Five-toed Skink, *Leptosiaphos graueri*	F	AR		☐	
Red-flanked Skink, *Mochlus hinkeli*	FN			☐	☐
Speckle-lipped Skink, *Trachylepis maculilabris*	N			☐	
Long-tailed Skink, *Trachylepis megalura*	FN			☐	
Striped Skink, *Trachylepis striata*	N			☐	
TYPHLOPIDAE					
Angola Blind Snake, *Afrotyphlops angolensis*	N			☐	
COLUBRIDAE					
White-lipped Snake, *Crotaphopeltis hotamboeia*	N			☐	
Montane Egg-eater, *Dasypeltis atra*	FN			☐	
Gunther's Green Tree Snake, *Dispadoboa unicolor*	F			☐	
Boomslang, *Dispholidus typus*	FN			☐	
Angolan Green Snake, *Philothamnus angolensis*	N			☐	
Thirteen-scaled Green Snake, ***Philothamnus carinatus***	F			☐	
Rwanda Forest Green Snake, ***Philothamnus ruandae***	F	AR		☐	
Large-eyed Green Tree Snake, ***Rhamnophis aethiopissa***	F			☐	
Forest Twig Snake, *Telotornis kirtlandii*	FN			☐	
Jackson's Tree Snake, ***Thrasops jacksoni***	FN			☐	
Olive Marsh Snake, ***Natriciteres olivaceae***	FN			☐	
ATRACTASPIDIDAE					
Variable Burrowing Asp, *Atractaspis irregularis*	N			☐	
Pale-collared Snake-eater, *Polemon graueri*	F	AR		☐	
LAMPROPHIIDAE					
Olive House Snake, ***Boaedon olivaceus***	N			☐	
Cape File Snake, ***Limaformosa capensis***	N			☐	
Forest Wolf Snake, ***Lycophidion ornatum***	FN			☐	
Western Forest File Snake, ***Mehelya poensis***	F				
PSAMMOPHIIDAE					
Three-lined Grass Snake, ***Psammophylax tritaeniatus***	N			☐	

	Habitat	Biogeography	IUCN Status	Nyungwe	Cyamudongo
PSEUDOXYRHOPHIIDAE					
Slug-eater, *Duberria lutrix*	FN			☐	
ELAPIDAE					
Forest Cobra, *Naja melanoleuca*	FN			☐	
Jameson's Mamba, *Dendroaspis jamesoni*	F			☐	
VIPERIDAE					
Great Lakes Bush Viper, ***Atheris nitschei***	FN	AR		☐	
Puff Adder, ***Bitis arietans***	FN			☐	
Rhinoceros Viper, ***Bitis nasicornis***	F			☐	
Incertae sedis					
Pale-headed forest snake, ***Buhoma depressiceps***	F			☐	

Appendix B4. Amphibians of Nyungwe National Park

According to J.M. Dehling, E. Fischer, U. Sinch, B. Dumbo, H. Hinkel & H.H. Hinkel (2022)

Habitat: F= forest, N=Non-Forest, A=Aquatic.
Biogeography: AR= endemic to the Albertin Rift; Rw= only in Rwanda.
IUCN status: VU= vulnerable, En= endangered, Cr= critically endangered.
Nyungwe/Cyamudongo: ☐= present.

	Habitat	Biogeography	IUCN Status	Nyungwe	Cyamudongo
ARTHROLEPTIDAE					
Arthroleptis adolfifriderici	F	AR		☐	
Arthroleptis schubotzi	FN	AR		☐	
Cardioglossa cyaneospila	F	AR		☐	
Leptopelis cf. cinnamomeus	N	AR		☐	
Leptopelis karissimbiensis	F	AR	Vu	☐	
BUFONIDAE					
Sclerophrys kisoloensis	FN	AR		☐	
HYPEROLIIDAE					
Afrixalus cf. laevis	F	AR		☐	
Afrixalus orophilus	F	AR		☐	
Callixalus pictus	F	AR	Vu	☐	
Hylambates verrucosus	F	AR		☐	
Hyperolius castaneus	F	AR		☐	
Hyperolius discodactylus	F	AR		☐	
Hyperolius frontalis	F	AR		☐	
Hyperolius jackie	F	Rw		☐	
Hyperolius kivuensis	N			☐	
Hyperolius lateralis	FN	AR		☐	
Hyperolius paralellus	N			☐	
Hyperolius viridiflavus	N			☐	
Kassina senegalensis	N			☐	
PHRYNOBATRACHIDAE					
Phrynobatrachus acutirostris	F	AR		☐	
Phrynobatrachus graueri	F	AR		☐	
Phrynobatrachus natalensis	N			☐	
Phrynobatrechus parvulus	N			☐	
Phrynobatrachus versicolor	F	AR		☐	
PIPIDAE					
Xenopus victorianus	N			☐	
Xenopus wittei	FN	AR		☐	
PTYCHADENIDAE					
Ptychadena anchietae	N			☐	
Ptychadena chrysogaster	FN	AR		☐	
Ptychadena nilotica	N			☐	
PYXICEPHALIDAE					
Amietia nitti	FN			☐	
HERPELIDAE					
Boulengerula fischeri	FN	Rw	VU		☐

Nyungwe Forest National Park

Long Term Sustainability Strategy 2022-2040

February 23

1. Introduction

- Nyungwe National Park is located in the south-west area of Rwanda, covering an area of 1,019km2, and with a topography ranging from 1,600-2,950m above sea level. The Nyungwe National Park includes Cyamudongo Natural Forest, an isolated 4km^2 area of forest situated approximately 10km from the Nyungwe forest.
- It forms part of the Albertine Rift Montane ecosystem which spans from Western Uganda, through Rwanda, Burundi and into north-western Tanzania. Nyungwe is the second largest area of intact mountain forest in the ecoregion, with the first in DRC which enjoys far less protections. Therefore, NNP is the largest and most protected area of Albertine Rift montane forest.
- The entire southern boundary of NNP borders Burundi, and is contiguous with Burundi's Kibira National Park.

Map of Nyungwe National Park in Rwanda and Kibira National Park in Burundi.

- Nyungwe National Park straddles the Congo-Nile divide, and belongs to two major river basins - the Congo Basin and Nile Basin. Rukarara River begins in NNP and drains into the Nyabarongo River, becoming the Kagera River which eventually drains into Lake Victoria. This hydrology system makes NNP one of the main sources for the White Nile.

- The Rwandan boundaries of Nyungwe have a buffer zone of varying size, largely comprised of eucalyptus. No fencing is in place, and human-wildlife conflict issues are relatively common, and the buffer zone is not well respected at present, with harvesting of resources occurring regularly.
- Following a successful partnership between African Parks and the Rwandan government in managing Akagera National Park since 2010, African Parks was invited to manage Nyungwe National Park, signing a 20-year agreement 1st October 2020 with the Rwandan Development Board, a government institution mandated to accelerate Rwanda's economic development by enabling private sector growth. RDB's mandate includes Tourism and Conservation. The Nyungwe Management Company Ltd. was formed and registered in Rwanda as a legal for-profit entity to manage the park. The company is overseen by a 7-member board comprising representatives of Rwandan government, African Parks and the private sector.
- Rwanda is highly organized in a hierarchical governance structure starting with a national government, then a subdivision into five provinces – Kigali, Eastern, Western, Northern and Southern. Each province is then subdivided into gradually smaller administrative areas from districts, to sectors, to cells and then villages. Each level has a leadership structure. Nyungwe National Park is in both the Southern and Western Provinces of Rwanda, and borders on five districts. Within the districts are 24 sectors, 53 cells, and 141 villages. Strong relations at all government levels are key to operational success, particularly for community-related activities.
- Rwanda is politically and socially stable, with a strong and motivated Government with ambitious goals to bring the country to middle-income status in 2035, and high-income status in 2050. The government has placed conservation and environmental protections as a central policy alongside socioeconomic development, with a healthy environment recognized as a fundamental human right. Nature-based tourism of the four national parks was strategically identified as key economic contributor in income and employment.
- NNP is currently a candidate for a UNESCO World Heritage Site listing.
- NNP is recognised as an area of exceptional biodiversity and, as well as important forest habitats, also encompasses peat bogs, bamboo thickets, moors and grasslands.
- The Albertine Rift Forest region and NNP has a high level of endemism across all fauna and flora. NNP has more than 1,100 plant species (with at least 265 endemic to the mountains), including over 140 orchid species; 345 recorded bird species, with 30-40 Albertine Rift

endemic species; 43 recorded reptile species (8 endemic); 32 recorded amphibian species (15 endemic); and 300 recorded butterfly species, of which 30 are endemic.

- NNP is a habitat for 85 mammal species, 16 of which are endemic, and including 13 primate species - 12% of all African mainland primate species - including the near-endemic L'Hoest's monkey and Angola colobus, and the endangered Eastern Chimpanzee.
- Four mammalian forest species native to the area are now locally extinct – giant forest hog, buffalo, savanna elephant and leopard. These are candidates for reintroductions.
- Rwanda is a signatory to the following international conventions governing wildlife and environmental policy.
    - CITES
    - United Nations Framework Convention for Climate Change (UNFCCC)
    - Paris Agreement
    - Convention on Biological Diversity
    - United Nations Convention to Combat Desertification
    - Convention on the Conservation of Migratory Species of Wild Animals
    - Vienna Convention for the Protection of the Ozone Layer
- Key management documents for the park include a rolling 5 Year Business Plan, anchored to the long-term sustainability goals of the LTSS, and renewed and adapted every year; the Tourism Development Plan, which includes land use planning relevant to tourism. A Community Engagement Strategy is embedded in the 5 Year Business Plan but is also being adapted into a stand-alone document.
- Nyungwe, as a chimp-trekking destination, has been a lesser-known tourism offering within East Africa, with a lack of accommodation and easy logistics playing a role, but awareness has increased significantly of late.
- NNP is categorized as a Category I park, under the African Parks conceptual model of Optimization and Sustainability, meaning it has the potential to be >75% self-financing. Current projections based on tourism income has NNP achieving self-sustainability in 2038.

2. Scope and Purpose for this Strategy

The Long-Term Sustainability Strategy (LTSS) of Nyungwe NP is fully aligned with AP's mandate and mission stipulated in the public-private partnership agreement signed between AP and the Rwandan government.

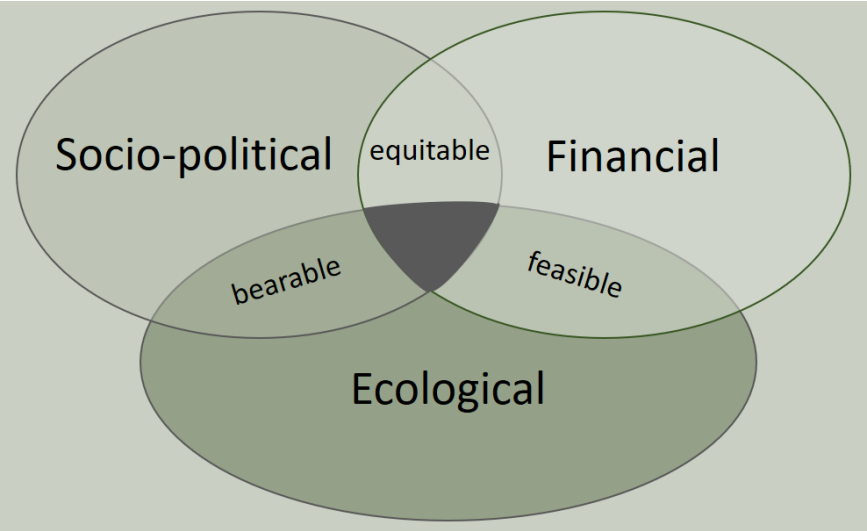
It provides an overarching management strategy for the Park and is designed to articulate what long-term impacts should be achieved in the park in terms of ecological, socio-political and financial sustainability, as well as the key management approaches that are required to ensure that these impacts are realized. The LTSS guides the development of the Management Plan required by government, as well as the Land Use Plan that outlines the activities permitted in different parts of the park. The LTSS also provides the context for prioritising the park's rolling Five-Year Business Plans (5YBPs), with departmental plans and annual plans nested within these 5YBPs.

The objectives laid out in the Five-Year Business Plan as well in [park name] NP's Community Engagement strategy will contribute directly towards the achievement of these long-term impacts defined in this Strategy. Having long-term impacts on these three levels contributes directly to African Parks Mission:

To have conservation impact in Africa for the benefit of both wildlife and people through the management of a diverse portfolio of protected areas that is ecologically, socially and financially sustainable.

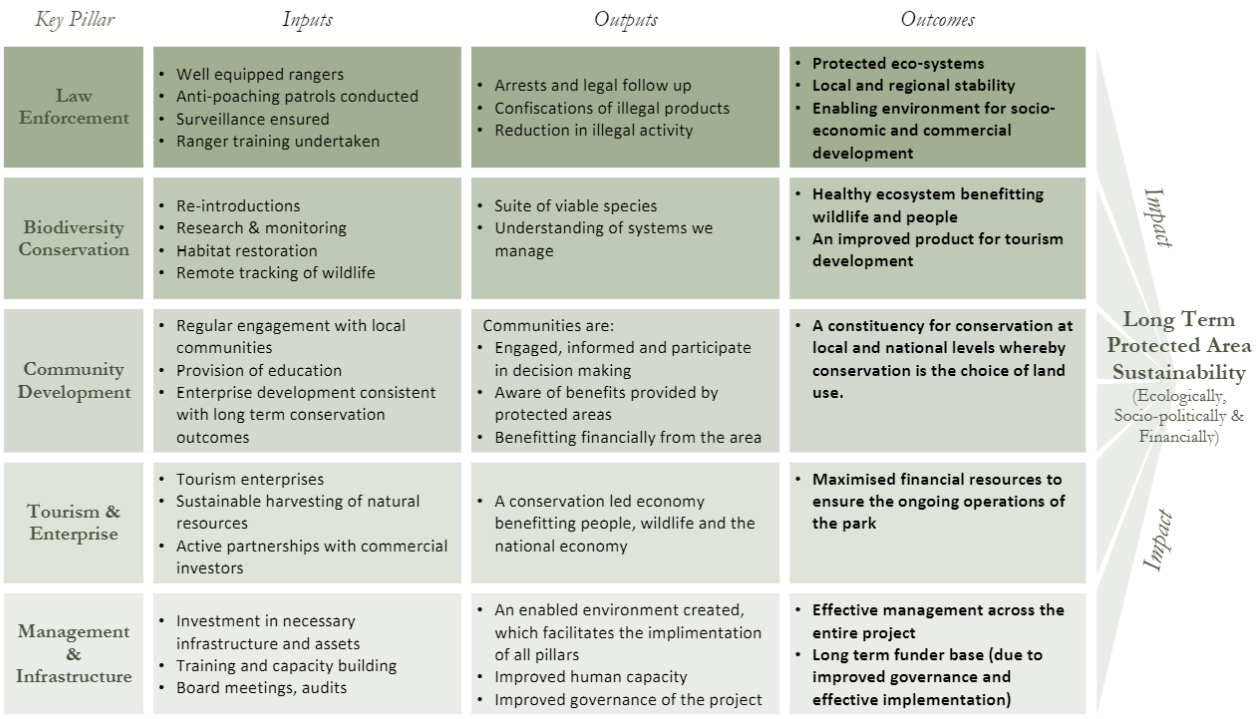
3. Ensuring Overall Sustainability

Overall sustainability of any system requires ecological, socio-political and financial sustainability, which depends not only on each component in isolation, but also on the ways in which these components interact with one another. Management towards ecological sustainability therefore needs to be bearable by society, and socio-political sustainability bearable by ecosystems. Similarly, managing for financial sustainability should be equitable across society and feasible in terms of available (renewable) ecosystem resources. This also implies that none of the components of sustainability should have negative impacts on one another, or overall sustainability will not be realized. Consequently, strategic planning and decision-making needs to fully integrate the components of ecological, socio-political and financial sustainability, including consideration of the potential negative (or positive) effects that they have on one another.



Diagrammatic representation of the three components of overall sustainability of a protected area, and their influences on one another.

The sections that follow provide the integrated long-term strategy for ensuring overall sustainability of the park. They do so by first articulating the park's vision for achieving overall sustainability, along with the ecological, socio-political and financial impacts that must be achieved in order to realize its vision (Section 4). The current status of each of these components of sustainability, along with a horizon scan of how this context may be expected to change in the future, is provided below each impact. Thereafter (Section 5), the various, integrated approaches to achieve these impacts are detailed according to each of the five key pillars of AP's operations (Biodiversity Conservation, Community Development, Tourism and Enterprise, Law Enforcement, and Management and Infrastructure).



The 5 key pillars of AP's operations towards achieving overall sustainability of protected areas.

The park's research priorities are defined around closing key knowledge gaps that are required for evidence-based decision-making – these are fleshed out in the park's Research Framework. The park's Monitoring Program is built around testing the various Theories of Change towards achieving each Impact, while simultaneously evaluating management performance. Together the Research Framework and Monitoring Program support the adaptive management of the park.

4. Vision and Impacts

The Long-Term Sustainability Strategy is underpinned by two key aspirations for the future of Nyungwe NP. The first is an overall vision for the desired state of the park, a picture of the future that reflects the restoration and maintenance of all that makes the park unique and conservation-worthy in perpetuity. The second is the articulation of a set of three component impacts (ecological, socio-political and financial) that are prerequisites for achieving overall sustainability for the park.

The Vision for Nyungwe Forest NP is:

Nyungwe National Park is the largest intact and profitable Albertine rainforest landscape owned by communities.

In order to achieve this vision, Nyungwe NP will need to manage for the following desired impacts towards overall sustainability:

4.1 Ecological Sustainability

Current ecological context

- Nyungwe is the **second largest area of intact Albertine Rift Montane Forest**, a vegetation type restricted to the western section of the Albertine Rift. With the first largest in the Democratic Republic of the Congo, Nyungwe is **the largest *and* best protected**.
- Nyungwe National Park is recognized as an area of **exceptional biodiversity**, and with a **high level of endemism**. More than 1,100 plant species (at least 265 are endemic to these mountains), including over 140 orchid species. 345 bird species, with 30 endemics; 43 reptile species, with 8 endemic; 32 amphibian species, with 15 endemic; nearly 300 butterfly species, with 30 endemic.
- NNP hosts **13 primate species**, which is 12% of all African mainland primate species, including the near-endemic L'oest's monkey and Angolan Colobus, as well as endangered **Chimpanzees**.
- Nyungwe serves as Rwanda's **largest water catchment area**, with suggestions that it provides up to 70% of Rwanda's fresh water, however this needs scientific verification. Nyungwe is recognized as a **key source of the Nile**, so its health as an ecosystem has far-reaching implications across the continent.
- Four mammalian forest species native to the area were extirpated – **giant forest hog**, **buffalo**, **savanna elephant** and **leopard**. Restoration of the ecosystem will include **reintroduction** of the species to resume their key roles within the ecosystem.
- In securing the Nyungwe ecosystem successfully, NNP can become a **safe haven** for other forest-adapted **species of conservation concern**, such as Lowland Gorilla.
- **Cyamudongo Forest**, which hosts a **small population of Chimpanzee,** is a small section of forest 4km^2 in area which was once joined to Nyungwe National Park, but is since separated with human-populated agricultural lands between. Administratively, Cyamudongo Forest falls under the remit of Nyungwe management. A long-term vision would reincorporate Cyamudongo and other identified small forest patches in the region into the greater Nyungwe forest to create **contiguous ecosystems**, particularly for genetic management of faunal populations.

Horizon scan

- Climate change is anticipated to cause shorter but more intense wet seasons. Changes to seasonality will have impacts on both vegetation and wildlife, particularly those with highly-specialised adaptations. Temperatures will increase, and it has already been observed that birds adapted to temperatures at specific attitudes have migrated to higher territories in the forest. Climate changes will also be significant impacts on agriculture and land productivity in surrounding community areas.
- **Zoonoses and the reverse** pose a particular threat to **Chimpanzees** but, as with any ecosystem in close proximity to human disturbance, Nyungwe is susceptible to any potentially devastating **faunal and floral disease**, such as **diseases carried by livestock**.

The desired Ecological Impact for the park is therefore:

Nyungwe Forest National Park is the largest, intact and protected Albertine Rift montane rainforest ecosystem.

4.2 Socio-political Sustainability

Current socio-political context

- The isolated nature of the communities of Nyungwe, and limited land productivity due to dramatic topography, means people have a **relatively high dependency on forest resources**, which is currently being **harvested in an unsustainable manner**. These include **bush meat**, **livestock fodder**, **timber**, **honey**, **medicinal plants** and **gold**, but perhaps most importantly, **fresh water**, which is relied on by Rwanda, and beyond its borders as a source of the White Nile River. To ensure the forest can continue to provide for regional and continental communities, **resources will need to be sustainably managed**, and alternative sustainable sources found where possible.
- A dense population and less productive terrain makes **land a scarce resource**. Conservation is a land use choice that may not be necessarily viewed positively by all community members, where **subsistence agriculture is still a primary source of livelihoods**. NNP must bring positive socioeconomic benefits to communities to help justify the choice of land use.
- NNP enjoys a **high level of government support**, with a government who has **prioritized conservation and environment-centred policies**. NNP also forms a key part of the **government's tourism strategy**, which in turn is a significant component of the country's National Strategy for Transformation, and Vision 2050 aiming to make Rwanda a high-income country by 2050.
- **Conservation and environmental awareness** is being integrated into the national education system. While the curriculum is in the process of being rolled out, NNP plays an immediate key role in educating adjacent community members to the importance of conservation, through the community education program.
- NNP's **buffer zone** is currently under the management of the government, with concessions for timber extraction awarded. There is untapped potential for a comprehensive management program that can bring **benefits to both conservation and communities**, through demonstrating **conservation-led business enterprises**, such as well-managed sustainable **agroforestry**.

Horizon scan

- **Global events**, such as a pandemic or financial crisis, can affect Nyungwe on numerous levels from **disrupting income streams**, to **changing government priorities**. Management strategies of Nyungwe should allow for **preparedness and adaptability** to weather these events.
- **Regional instability presents a threat to NNP** from directly neighbouring Burundi, and relatively close DRC. A significant national security focus is already in place, and future investment in border security is likely to remain a high priority.
- A breakout of conflict in neighbouring countries could lead to **an influx of refugees**, which may put pressure on a landscape already accommodating a high density of people. This could impact the resources and even boundaries of NNP.

The desired Socio-political Impact for the park is therefore that:
Communities have a sense of ownership of the park, and identify with it, helping secure long-term support for the park's existence.

4.3 Financial Sustainability

Current financial context

- **Tourism is a main source of revenue** for NNP, however as an ecosystem of high carbon-storage capacity and a biodiversity hotspot, it has high potential for significant income

streams from **green funding**. NNP is also a key provider of some **ecosystem services**, such as fresh water, and as the value of these are understood and appreciated there is potential for developing revenue for the services rendered. In current projections, NNP is anticipated to become **self-financing** from tourism alone by 2038, however with green funding and ecosystem services payments, self-financing could be achieved much earlier, and therefore the ultimate goal of **profitability** achieved quicker.

- NNP's business plan strategizes for **diversified streams of revenue** to achieve **financial robustness** and **safeguard against financial disruptions**. Tourism is identified as a key money earner, with the Tourism Development Plan setting out the vision for a diversified tourism strategy aimed at various markets, including the domestic market. Green financing, agroforestry and other **sustainable agricultural endeavours** will bolster NNP's earning capacity.
- NNP is a nascent park in the AP portfolio, so the early years are characterized with large CAPEX the growing team necessary to manage all operations of the park, however these costs should **plateau and stabilize**, rising only with inflation and other economic factors. All CAPEX investment strategies will seek to **create efficiencies and minimize OPEX costs**.

Horizon scan

- **Extreme global or regional events**, such as a global financial crisis or pandemic, can negatively impact NNP revenue streams, particularly tourism. A **diverse and robust array of revenues** should help mitigate such impacts.
- Africa has historically experienced negative impacts to tourism from regional or continental events due to continental misconceptions. While Rwanda remains stable, an **escalation of regional insecurity** has been identified as a **real potential threat**, and as such NNP needs to be prepared to weather the financial implications should this happen.

The desired Financial Impact for the park is therefore that:
Nyungwe Forest NP is profitable, bringing economic benefits to Rwanda.

5. Approaches for achieving the desired impacts, using African Parks' five key pillars of operation

The section that follows outlines the key outcomes that will need to be achieved in order to have the desired ecological, socio-political and financial impacts in Nyungwe NP, along with the proposed approaches to achieve these outcomes. They are presented according to the five pillars of African Parks' operations, so as to enable the derivation of park's rolling 5-Year Business Plans.

5.1 Biodiversity Conservation

1. <u>The diverse mosaic of vegetation types of Nyungwe, including primary forests, bamboo thickets, peat bogs, moors and high-altitude grasslands, are intact and healthy.</u>

    - **Primary forests are contiguous, healthy, intact and balanced**, replicating historical compositions of vegetation under similar climatic conditions. This will be achieved by **preventing fragmentation** (through careful infrastructure planning and usage control, and illegal activities prevention and monitoring), **stopping illegal logging** (by providing alternative

options such as agroforestry), **eliminating human-induced fires** (through law enforcement, awareness campaigns teaching beekeeping best-practices and effective fire-fighting methods) and **assisted regeneration of secondary forests** to reinstate normal forest succession processes. The park must have effective fire-fighting capacity in place to mitigate damage.

- Other key vegetation areas characteristic of Albertine Montane forest such as the **bamboo thickets, peat wetlands/bogs, subalpine forests, moors and wooded grasslands** are **compositionally intact**. This will be achieved via **eliminating unsustainable and illegal harvesting of bamboo**, **medicinal plants**, and **firewood**, by providing sustainable alternatives to communities (such as teaching cultivation and use of energy-efficient cooking products). **Illegal farming incursions into the park will need to be controlled**, and **agriculture in peripheral areas must utilize sustainable methods** to reduce impact on the forest.

- **Alien species within the forest have been eradicated**, and only exist in the buffer where they are sustainably managed as a resource (e.g. eucalyptus).

2. Nyungwe is host to a thriving suite of diverse wildlife species characteristic of Albertine Rift montane ecosystem, that were historically present during similar climatic conditions.

    - Key species for NNP are identified by the following criteria:
        - Conservation Status/Charismatic Species
            - Eastern Chimpanzees
            - Owl-faced monekys
            - L'Hoest Monkey
            - Angolan Colobus
        - Albertine Rift Montane Endemic
            - All endemic birds (30 species)
            - Hill's Horseshoe bat
            - Lestrade Duiker
        - Species heavily poached
            - Gambian Pouched Rat
            - African Brush-tailed Porcupines
            - Black-fronter Duiker
            - Yellow-backed Duiker
            - Bush Pigs
        - All reintroduced/introduced species
            - Elephant
            - Buffalo
            - Giant Forest Hog

    - Key species will act as indicators of overall biodiversity health. It will be necessary to understand and manage the drivers (both positive and negative) of their population dynamics (births, deaths, immigration and emigration).
        - **Births** - through ensuring **adequate habitat for forage and shelter**.
        - **Mortalities** – by **eliminating poaching** as a threat, and **managing disease**.
        - **Dispersal** – **reintroductions** and **supplementation** help **mimic natural patterns** of **emigration and immigration**, maintaining **genetic integrity**. Advocating for controlled use of the national road to reduce impact on natural animal migrations.

- Through effective park management NNP aspires to become a **viable safe haven** for the protection of **species of global conservation concern** that are suitably adapted to the ecosystem, helping prevent extinction. An example is Eastern Lowland Gorilla.

3. Ecosystem connectivity has been achieved by expanding the effectively managed area of Nyungwe, to allow for larger landscape processes to occur, including the ability for species to adapt to a changing climate.

    - To achieve this, **intact forest fragments** (including Cyamudongo Forest) will be incorporated into the park area via protected corridors.
    - The larger **NNP & Kibira forest landscape** must remain **complete and unfragmented**. To achieve this for the long-term, it will be necessary for collaborative cross-border management. A most ideal scenario will be homogenous management across both parks.
    - NNP **buffer zone** management must be compatible with the management goals of the park, and should **positively impact the community**. The buffer must serve as an **expansion of the ecosystem**, with native vegetation re-established, while **sustainable use/harvesting** (such as forestry) of natives and non-natives will provide a source of funding to the park.

5. NNP is a functional water tower and continues to serve as a primary source of fresh water for Rwanda and as a key source of the Nile.

- To maintain an appropriate freshwater hydrological regime, ensuring **healthy water quality** and **uninhibited natural water flows,** which support biodiversity and human needs, it will be necessary to **eliminate artisanal mining, deforestation** and **pollution linked to infrastructure**.

6. NNP's soil continues to play a key role in the overall balance and health of the ecosystem.

- **Erosion must be minimized** through **restoration** of areas with **degraded forest cover, replacement of exotics with natives,** and minimization of **infrastructure-driven degradation.**

7. Climate change effects are best know and planned for.

- **Predicted effects of climate change** and their effects on vegetation and animal physiology will need to be understood to develop appropriate **mitigation and adaption measures.**

5.2 Community Development

The required community development outcomes for [park name] are presented within the framework of the 3 E's of the community development approach taken by African Parks (i.e. Education, Engagement and Enterprise):

Education: Communities understand the park's ecology and relevance to their lives.

1. Communities have a sound understanding of the importance of a healthy environment.

- **Community** members have a **positive and sustainable relationship** with the park, **viewing it as an asset**. This will be achieved via **educational activities** such as facilitated visits to park for

school pupils and local leaders, student eco clubs, community social events, and media communications (e.g. radio) which help disseminate useful and community-relevant information about the park and conservation.

- **Communities are aware of the tangible benefits of park conservation**. This will be achieved through communicating success stories via staff-community interactions, media and branding of park-supported projects for knowledge.

Engagement: The park maintains good relationships with all stakeholders, who are involved in decision-making.

1. The existing administrative structure of Rwanda is effectively used to ensure representation in engagement programs and contributions to decision-making.

- To achieve maximum impact, NNP must align its **community engagement strategy** (3E's) with government strategies (i.e. District Development Strategy, National Strategy for Transformation and Vision 2050). **Maintaining positive relationships** with **authorities and leaders** at each governance level will be key to success.

2. Nyungwe management has a firm understanding of the basic needs of communities, and these are incorporated into management strategies.

- NNP will need to operate an engagement plan centring on **two-way communications**, ensuring the **needs of the communities** are heard, understood and incorporated into park management plans.

3. Communities have high awareness of the benefits/opportunities provided by the effective conservation of the park

- **NNP staff must be ambassadors for the park**, helping build awareness of park benefits in all community interactions. Regular community meetings and participation in Umuganda will serve to communicate the park impacts and create goodwill.

Economy: Community livelihoods are enhanced because of the existence of the park

1. There is coexistence between humans and wildlife, with little or mitigated effects of HWC.

- **Raiding of crops and bee-hives**, **livestock loss** and **human injury**, will be prevented, or minimized, through effective HWC prevention measures or mitigated through compensation.

2. Conservation-led enterprise developments are sustainable in the long-term and bringing economic benefits to a wide range of community members.

- NNP must help **community enterprises gain access** to wider **national and international markets** for the long-term viability of businesses.
- **Sustainable agro-forestry** will be developed to provide **economic benefits** for both **community** and the **park**.
- **Sustainable fish farming** will be explored for stimulating **local economic benefits** while addressing **nutritional deficits**.

- NNP must continue to **source all goods and services** locally where possible, generating economic benefits tied directly to the conservation of the park.

3. Revenue from tourism is contributed to community development via a revenue sharing scheme.

- As well as timely **contribution of a percentage of revenue**, NNP must also maintain an active involvement in the **selection and distribution process** for the revenue sharing, supporting the most impactful community projects.

4. The majority of staff in the park are employed from within the five districts bordering the park, and all staff are from Rwanda.

- **Training and internship programs** will ensure a viable pool of skilled candidates is available locally to fill positions. A motivated workforce, using **recognition**, **incentives**, **opportunities and careful succession planning**, will ensure low staff turnover.

5. Community enterprises based on eco system services (e.g. clean water) bring economic benefits.

- Communities will be empowered to recognise and harness **eco system services as a sustainable livelihood improvement opportunity**, incentivizing the further protection of the forest.

5.3 Tourism and Enterprise

1. Diversified income to the park ensures financial robustness for a profitable park, not reliant on donor income.

- It will be necessary to have a **comprehensive, diversified and informed tourism strategy** in place to ensure tourism is a significant contributor to park revenue. A relevant and up-to-date **Tourism Development Plan** will identify challenges and barriers (such as access and product diversity) and provides strategic solutions.
- NNP's **financial self-sustainability** will be leveraged as a success story for building African Parks donor relations. **Donors relations** will be maintained through funding of **key special projects** in NNP, such as reintroductions.
- **Green financing** and **monetized eco system services** will constitute a **significant portion of income** (inc. carbon credits; biodiversity credits; provision of clean water; air filtrations services etc).
- **Conservation-led initiatives** with communities will provide **additional revenue streams** to NNP, while **creating economic opportunities for communities** (e.g. fish farm, agro-forestry). The **buffer zone will generate income** for NNP through agroforestry. Other potential sources of revenue will be continually explored.

2. Nyungwe achieves financial sustainability by ensuring net income covers all operational and capital costs. Special projects cover needs of park outside of core budget.

- NNP and Akagera National Park, while both are managed by African Parks, will **share resources** and find **synergies** that **promote cost-saving and efficiencies** in the operations of both parks.

- Cost savings will be achieved through **local sourcing of materials** & **service providers**, helping avoid costly import duties and tariffs.
- The use of **technology** and creation of **efficient systems** will be necessary to help achieve **cost-saving** across various operational departments.

5.4 Law Enforcement

Given the threats to achieving NNP's Vision outlined above, law enforcement in the park will need to focus primarily on:

- Eliminating **poaching**, **illegal mining**, **plants/tree harvesting** and **fires** as the key threats to NNP.
- Special focus is given to the **prevention of fires**, as the singularly largest threat to NNP's biodiversity. Illegal and unmanaged honey harvesting will need to be continually controlled.
- A **multifaceted approach** to law enforcement must ensure **comprehensive coverage** of the entire protected area. This will be achieved via a number of factors:
    - Maintaining a well-trained, well-equipped and motivated law enforcement unit.
    - Adequate **communication** and **access infrastructure** will be created to overcome NNP **challenging terrain**.
    - **Aerial surveys** conducted by helicopter or drone will be used to compliment ground coverage.
    - Sophisticated but efficient **technologies** will be rolled out, enabling **data-driven strategizing**.
    - Close collaboration with the community team for effective **community interventions**.
- **Cross-border threats** will be mitigated through strong collaborative partnerships with government security bodies.
- Use of the national road transecting NNP will continue to be monitored by rangers, with intervention to dangerous driving to reduce threats to wildlife.

5.5 Management and Infrastructure to enable ecological, socio-political and financial sustainability

- **Development and infrastructure** within the park will always be restrained and strategic, and **minimize fragmentation of habitats.**
- Tourism infrastructure will seek to **improve existing facilities**, **add only strategic new facilities** and **improve accessibility** for the efficient and profitable running of tourism activities, as a key revenue generator for the park.
- Connecting communities to overcome challenges of isolation.

6. End of Mandate Strategy

The partnership agreement signed in 2020 with the Rwandan government provides for an initial term of 20 years, renewable. The agreement also stipulates five-yearly evaluations of the effectiveness of the partnership and AP management through the use of an expert jointly mandated by both parties. The option for renewal is expected that they will be based on the various conclusions and recommendations of the five-year assessments and will focus on demonstrating the progress made in achieving the outcomes and impacts set out in the park's long-term strategy.

- Conditions for AP to consider an end for its management of NNP in 2040 would either be that its vision is achieved as measured by:

1. Skilled and trained locally-basd management are ready to successfully continue the park's operations, towards achieving financial ecological and socio-political sustainability.
2. Enduring positive relationship between the government and the management team.
3. Sustainable and robust revenue streams, or financial mechanisms (e.g. a trust) in place to ensure future ongoing profitability of the park, and covering all operational costs.
4. Nyungwe National Park is viewed across the population as a national asset.
5. Wildlife populations are safe from illegal activities, thriving and well-managed, contributing to the overall health of the ecosystem.

Or, in contrast, that AP can no longer continue its management due to:

1. A force majeure situation (natural or socio-political) that cannot be resolved.
2. A change of government priorities that renders the park unmanageable due to lack of support.
3. The funding required to operate the park cannot be attained
4. A new agreement with satisfactory terms cannot be reached with the Government of Rwanda.

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REPORT TO THE RWANDA DEVELOPMENT BOARD AND NYUNGWE MANAGEMENT COMPANY ON THE FEASIBILITY OF TRANSLOCATING ELEPHANTS TO NYUNGWE NATIONAL PARK.

1. Background

Nyungwe National Park is a 101 900ha protected area in the southwest of Rwanda. African Parks currently have a 20-year management agreement with the Rwanda Development Board and have formed the Nyungwe Management Company (NMC) as a vehicle for the protection and development of this unique Afromontane Forest system. This protected area is approximately 2400m in altitude with varying vegetation types but is mostly dominated by dense rainforest. This system supports smaller areas of shrub savannas but mostly dominated by rainforest rich in plant diversity. The variety of the plant habitats also supports a good diversity of wildlife species, several which are endemic to Nyungwe.

Although it is currently unclear as to the historical occurrence and density of elephants within the park, the NMC is considering a strategic introduction of a founder population of elephants to Nyungwe for ecological and tourism reasons.

2. Objectives and recommendation.

It is thought that *Loxodonta cyclotis* or perhaps a mix of *Loxodonta cyclotis africanus* historically occurred within the thickly forested western and southwestern part of Rwanda.

There is currently a small resident population of approximately 140 elephants in the east of Rwanda in Akagera National Park. The origin of these elephants is well known, 23 animals were translocated from Bugusera to Akagera in the 1975 (pers. comm Gruner). Although the genetic subspeciation of the Akagera elephants is currently unknown, subjectively they seem to have phenotypic characteristics of both savannah and forest elephants. Given the short distance between Bugusera and Nyungwe, it is very likely that the Bugusera elephants would have been genetically very similar to the elephants that historically occurred within the Nyungwe biome.

Given the facts above it would make sense to translocate elephants from Akagera to Nyungwe rather than bringing elephants from elsewhere. Introducing elephants from outside the borders of Rwanda will be complex and there is a strong possibility of maladaptation to the forest environment.

It is recommended that a founder population of approximately 20 elephants be moved to the Wasenkoko area of Nyungwe. Wasenkoko has been chosen as a release site due to easy road access for heavy vehicles. There is plenty of water and food resources and a mosaic of savannah and forest habitats which should give the introduced elephants a good chance of adapting to their new environment.

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3. Elephant capture and translocation.

Albeit difficult, conditions and terrain at Akagera make it possible to execute an elephant capture operation. Elephant translocation is a very specific process and requires the right equipment and human resources. The key to the success of elephant introductions is to identify, capture and translocate entire cohesive family groups of 5 to 15 animals. These family groups of elephants will be identified from the air, chemically immobilized, and loaded by a dedicated crew of experience elephant translocators. Once capture and recovery is complete, they will be transported by road to Nyungwe

Purpose built capture and recovery equipment will be required to load and recover elephants in the field. Separate transport containers will be needed to transport the elephants by road. It is calculated that approximately 4 to 5 elephants can be to be transported in one transport crate at a time. A suitable offloading point will have to be constructed well within the park boundaries. At this point a hard base turning circle (50m x 50m) will be required to adequately manoeuvre the large elephant transport vehicles for offloading

A detailed list of material requirements is listed in the next paragraph. All the required recovery modules and transport crates can be manufactured by Conservation Solutions at their manufacturing plant in South Africa and shipped to Rwanda.

4. Human and material resources required for a translocation operation.

4.1 Human resources

A crew of at least 10 capture attendants from Akagera will be required to assist with the capture exercise within Akagera National Park.

The core capture team will consist of the following experienced staff:

- Veterinarian — Conservation Solutions.
- Logistics and capture manager — Conservation Solutions.
- Two truck crane operators — Locally sourced.
- Two lowbed truck drivers — Locally sourced.
- Two Conservation Solutions ground crew — Conservation Solutions.
- Pilot — Experienced elephant capture pilot CS.

A police escort will be required during the transportation of the elephants.

4.2 Material Resources including logistical demands

Below is a list of essential equipment which will be needed to undertake a capture and transport operation for family groups of elephants within Akagera. It is important to note that the translocation of large adult bulls requires a totally different set of recovery and transport crates.

- 1 x 6m long elephant family group recovery box.
- 2 x 6m long custom-built elephant family transport containers to be constructed in South Africa and shipped to Rwanda.

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- 2 x rigid crane truck (minimum 23 000lbs/m lifting capacity) for field recovery and transport of elephants (Sourced locally).
- 2 additional double axle truck tractors (min 300Hp) with a minimum of 6m load space on a lowbed trailer to be hired locally for transport of the elephants. A lowbed transporter must be used to move elephants due to a lower centre of gravity which negates the risk of the elephant transporter toppling over. These trucks can be sourced locally.
- Assorted hoisting and pulling slings (Conservation Solutions).
- Veterinary equipment and drugs for immobilising and tranquilising elephants (Conservation Solutions).
- 1 x Helicopter (minimum of a 4-seater helicopter).

5. Overall feasibility

5.1. Capture of elephants at Akagera National Park and introduction to Nyungwe National Park

Given the information at hand, our conclusion from the assessment at Nyungwe and Akagera National Parks is that logistically, albeit difficult, it will be feasible to undertake a capture operation within the park subject to the following criteria:

- The capture is done in the dry season.
- The equipment and human resources to conduct the capture is in place (see materials)
- There is support from the Rwandan authorities.
- That Nyungwe has sufficient infrastructure to facilitate successful offloading, and release of the animals.
- The capacity is in place for post release monitoring and management.

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BIODIVERSITY SURVEY OF NYUNGWE NATIONAL PARK: 2009 -2014

WCS, 2014

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Many organizations and individuals contributed to gather biodiversity survey data used in this report. Our thanks go to Rwanda Development Board ï Tourism and Conservation (RDB-T&C) for collaboration and permission to conduct these surveys in Nyungwe National Park. We thank GEF-UNDP and USAID for providing funding for the 2009 and 2014 surveys respectively. We thank Andy Plumptre and Tim Oôbrien for their time and for providing methodological and analysis advice. Our thanks goes to Nicolas Ntare who took time to go through data analysis and writing of this report, thanks to Chloe Cipolletta and Felix Mulindahabi for their inputs in this report and the coordination of the survey. We are very grateful to WCS staff who participated in data collection of these surveys included, Niyigaba Protais, Ngirababyeyi Venerand, Gakima Jean Baptiste, Mureritesi Jean Bosco, Nzakizwanayo Eraste, Hakizimana Jacques, Nkurunziza Francois, Ntamunoza Augustin, Gatorano Gratien. RDB rangers included Sibomana Sylvain, Ntakirutimana John, Ababanyi John, Nsengiyumva Dieu Donne, Iyamuremye Jean dôAmour, Gatera Emmanuel and Muhoza Frederic. Drivers included Kamatari Francois and Mulindankaka Sylvestre. We thank Kitabi College of Conservation and Environmental Management (KCCEM) to avail 20 students of the 2014 academic year to participate in data collection; we thank Uwera Solange and Amani Gasana Mabano who participated in data collection and data entry during their internship at WCS.

EXECUTIVE SUMMARY

Covering a total area of 1,019 km^2 including the isolated forest of Cyamudongo, Nyungwe Forest was declared a National Park in 2005 and considered as an area of particular conservation interest in the Albertine rift due to endemism and species richness. This report compiles the results of two biodiversity survey carried out in 2009 and 2014. The aim of these surveys was to collect distribution, density and abundance data on mammal species in the Nyungwe National Park, document the patterns of human disturbance across the park and compare the 2014ôs results with those recorded 5 years earlier. Repeatedly park-wide survey provides data for monitoring changes of population density, distribution and abundance but also provides a basis for monitoring ecological changes and patterns of human use.

Data of the two surveys were collected across the whole park. The sampling excluded the forest fragments of Cyamudongo. In order to maximize consistency of sampling within the study area of Nyungwe National Park, 41 lines-transects of 3km each oriented north - south, with a random start point were used. For both years, data collection occurred throughout the months of June to September, typically months of dry season with the beginning of the wet season in September. In 2015, camera traps were deployed also at each start and end point of transect to record rare and discreet animal.

In total, direct observation of 13 species (12 mammals and 1 carnivore) were recorded in 2009 and 16 (15 mammals and 1 carnivore) in 2014 along line transect, while 11 birds and 23 mammals species were captured in camera traps in 2014. Encounter rate and density of species were calculated for primates and other mammal species. Chimpanzee density was calculated based on nest while density of duikers, bush pigs and carnivores were calculated based on indirect signs of dung.

For the 5 years interval between the 2 surveys, there was a variation in trends for different species: while duikersô density (all species combined) increased (from 0.85 duikers/km^2 in 2009 to 1.04 duiker/km^2 in 2014), bush pigs density decreased (from 0.98 bush pigs/km^2 in 2009 to 0.69 bush pig/km^2 in 2014) and density of chimpanzees was relatively stable (0.42 individual/km^2 and an estimated population of 430 chimpanzees in 2009 and density of 0.40 individuals/km^2 in 2014, with an estimated population of 407 chimpanzees).

Threats that affect this rich biodiversity hotspot are mostly anthropogenic including poaching, mining, fires, bamboo cutting, tree harvesting for firewood and house construction, livestock grazing, all exacerbated by the lack of alternative income-generating opportunities but also community mindset to natural resources. During this study, the illegal activities encounter rate increased significantly, from 0.038 in 2009 to 0.107 in 2014.

These results reflect also results of the data collected by rangers through the Ranger Based Monitoring program. Based on the results of these surveys, it is in the context of a human-dominated landscape that conservation

strategies must be developed in and around Nyungwe, scaling up the approaches aiming at providing alternative livelihoods while simultaneously increasing law enforcement to protect Nyungwe and its biodiversity.

INTRODUCTION

Located in the South West of Rwanda, Nyungwe National Park (1,019 km²) is the largest forest remaining in Rwanda and, together with the adjacent Kibira National Park (400km²) in North West Burundi, forms the Nyungwe-Kibira Landscape, part of the Albertine Rift, a globally important area for conservation due to its size, rich biodiversity and high levels of endemism (Plumptre et al, 2002; Vedder et al, 1992). Nyungwe is a montane forest (altitude range 1600-2950m) harboring a complex mosaic of vegetation types (Sun et al. 1996) including montane forest, savanna grassland, bamboo forest and high altitude wetlands such as Kamiranzovu swamp, one of the largest peat bogs in Africa (Fischer & Killman, 2008). The biodiversity of Nyungwe comprises thirteen primate species (20% of all primate species in Africa), 275 bird, 85 mammal, 32 amphibian, 38 reptile and 1068 plant species. Furthermore, there are 47 flowering plant species endemic to this forest (e.g. *Impatiens nyungwensis, Afromomum wuertii, Diaphananthe delepierreana, Ypsilopus liae*, etc.) and 280 species endemic to the Albertine Rift (Fischer & Killmann, 2008).

The reasons for the exceptional biodiversity found in Nyungwe and more broadly in the Albertine Rift may be explained by two key factors. First, during the last glacial period (around 20000 B.C.), animals and plants found refuge in high elevation, humid forests such as Nyungwe, formerly known as Rugege forest (Fischer & Killmann, 2008). Secondly, Nyungwe is located in a region where several large-scale biogeographical zones meet and the variety of terrestrial biomes provides a great span of microhabitats for a large number of plant and animal species. Due to this biodiversity, the Albertine Rift is one of the most important regions for conservation in Africa (Plumptre et al, 2007). This has resulted in the region being identified as an ñecoregionò of global conservation importance by WWF (Olson & Dinerstein, 1998; Burgess et al, 2004), by Conservation International as a ñbiodiversity hotspotò (Brooks et al, 2004) and by Birdlife International as an ñendemic bird areaò or ñImportant Bird Areaò (Stattersfield et al, 1998). Within the Albertine Rift, Nyungwe Forest has been recognized as a site of conservation priority due to its high number of endemic and endangered species (Plumptre et al, 2007; IUCN, 2008).

Nyungwe NP has been the focus of conservation efforts for more than 25 years. Over the last two decades Nyungwe has survived intensive encroachments and partial degazettement, contrary to Akagera National Park, which 60% of its area was degazetted, or Gishwati forest, where 80% of the original forest has been cleared (Webber, 2013). Nevertheless, Nyungwe still faces pressure from anthropogenic activities. The park is located in one of the most densely populated areas of the country, with high levels of poverty, resulting in very high pressure on the natural resources through poaching, illegal mining and habitat loss by fire, bamboo harvesting, and

encroachment. Illegal exploitation of forest resources has continued through time despite the designation of Nyungwe Forest as a National Park in 2005 (MINIJUST, 2006).

To curb the threats to the parkôs biodiversity, daily patrols are carried out by park rangers throughout the Park to control and monitor illegal activities in the Park. While on patrols, the park rangers record GPS coordinates at the start and end of each patrol, at the encounter of any evidence of illegal activities, animal sightings as well as at regular walk intervals, in what is referred to as Ranger Based Monitoring (RBM). The data collected by the park rangers during their patrols are then entered in a MIST-GIS computer program for processing geo-referenced data into information that will be used by the park managers to enable them to make timely and effective decisions for planning patrol and monitoring their effectiveness.

While RBM provides crucial information on the types, distribution and trends of illegal activities, knowledge on the species which live in the park, their distribution and trends through time is paramount in order to understand the biodiversity value of Nyungwe and to assess the effectiveness of conservation strategies towards protecting this biodiversity.

Since the first scientific exploration of Nyungwe, back in 1898 by Prussian Lt Count von Götzen, much effort has been devoted to catalogue and survey the biodiversity of this forest (Storz, 1982; Vedder, 1988; Dowsett, 1990; Fischer & Killmann, 2008; Kerbis & Ntare, 2009; Plumptre et al. 2002; Hinkel & Fischer, 1990; Plumptre et al, 2007; Menegon et al, 2009; Barakabuye, 2007 etc. to quote some).

During the small mammal surveys carried out in 2009 (Kerbis & Ntare, 2009 unpublished report), 13 species of small mammals were recorded for the first time in Nyungwe National Park including 7 shrew species (*Crocidura dolichura, C. niobe, C. sp. indet., Myosorex babaulti, Suncus hututsi, S. megalura,* and *Sylvisorex johnstoni*) and one otter shrew (*Micropotamogale ruwenzorii*). This was the first record of the otter shrew outside of the eastern Democratic Republic of Congo and hence the first record for East Africa. Overall, these surveys increased the known terrestrial small mammal list for the park by 38% (from 34 to 47 species).

During the 2009 survey, reptiles and amphibians were also surveyed to produce an inventory of the herptofauna of Nyungwe National Park. The survey sampled parts of the park by opportunistic search, with visual and acoustical monitoring of the habitat during the day and night. Forty three species have been recorded, of these 20 are amphibians and 23 reptiles. Among the species recorded, a new species of African glass frog *Hyperolius jackie* was described as new species to science in 2012 (Dehling M.J 2012).

However, it was not until 2009 that a park wide biodiversity survey covering the whole park was carried out. The purpose of the 2009 survey was to gather comprehensive data on the abundance and distribution of birds, mammals, plants and illegal activities across Nyungwe National Park, using a survey design which was robust and could be replicated for future comparisons and monitoring of trends over time. Given that wildlife monitoring in dense tropical forests is arduous and expensive, especially in difficult area to access, high altitude forests like Nyungwe National Park; it is generally recommended to replicate such survey efforts every 5 years.

This report presents the results of the 2009 survey and its replication carried out 5 years later, in 2014. The objective of this study is to present data on the distribution and abundance of medium and large mammals and the

illegal activities in Nyungwe National Park; assess the trends over time and investigate on the variables influencing those trends.

The 2014 survey was carried out with support from USAID project entitled ñSustaining Biodiversity Conservation in and around Nyungwe National Parkò. Thus, this report will inform park managers on the impact of the project and other conservation efforts on wildlife and human activities, providing park authorities with the quality scientific information necessary for long-term planning and management, and ultimately improve the effectiveness and sustainability of conservation efforts.

METHODOLOGY

The 2009 and 2014 park-wide surveys aimed to collect data across Nyungwe National Park, using the same methodology and design and as far as possible the same team members. In order to maximize evenness of sampling within the study area of Nyungwe National Park, Distance v. 6.0 (Thomas et al., 2009) was used to locate forty-one, 3km long line transects systematically in a north - south orientation, with a random start point (figure 1). The 41 transects were placed at a 3km distance between transects. For both years, data collection occurred throughout the months of June to September, typically months of dry season with the beginning of the wet season in September.

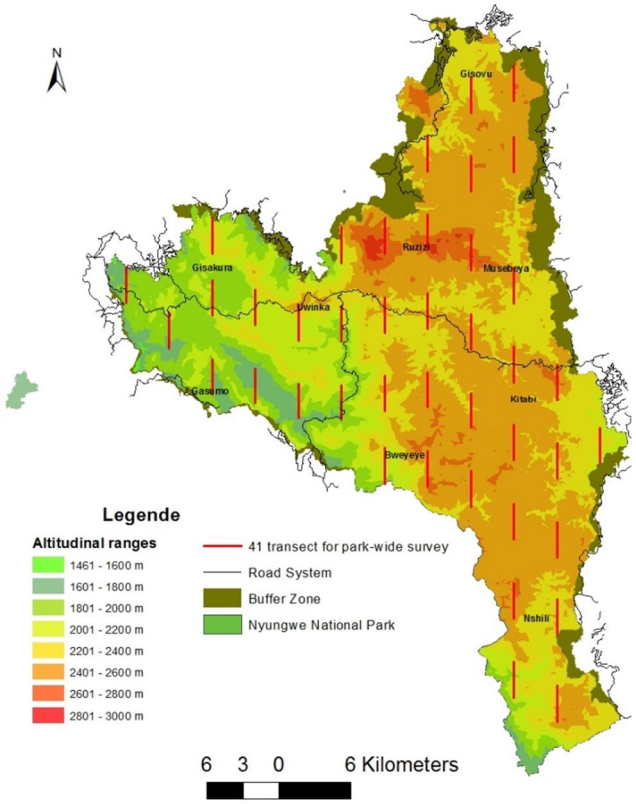


Figure 1. Park-wide survey transect design in Nyungwe National Park

The surveys involved 6 teams that worked simultaneously across the entire park and were composed of a principal observer responsible for sightings and a second observer who observed signs on the ground, including human sign.

Line transect sampling

Line transect sampling (Buckland et al. 2001) was used to record observations of large and medium ground dwelling mammals and arboreal species, notably primates (Plumptre & Reynolds, 1996). The same transects were also used to record human signs of illegal activities and indirect observation of animals. During the transect-cutting phase, only data on illegal activities and animal signs were collected (as the cutting noise would bias animal observations) and signs were either marked (for nests) or erased (for dung) to avoid recounts. For all indirect signs and direct observations, the perpendicular distance from transect to the center of the group was recorded using a tape meter or range finder and the total number of individuals was recorded as well as the age (status) of the sign.

During the survey, the following information was recorded:

(1)Marking distance interval: Distance was marked from the beginning 0m and every 250m to the end of transect. Habitat type was recorded at each 250 meters.

(2)Surveyors classified the habitat types as falling into one of the following eleven categories:

- Tall Closed Forest (TCF): 50% or more of the forest canopy is closed, trees >15m tall.
- Short Closed forest (SCF): 50% or more of the forest canopy is closed, trees <15m tall.
- Tall Open forest (TOF): less than 50% of the forest canopy is closed, trees >15m tall.
- Short Open forest (SOF): less than 50% of the forest canopy is closed, trees <15m tall.
- Clearing (CL): open areas of at least 20 m radius, without trees, that are dominated by *Sericostachys, Mimulopsis*, and other herbaceous or secondary vegetation.
- Human Clearing (HCL): human clearing through agriculture (crop or marijuana)
- Fern/burnt: forest gaps of at least 20m radius, without trees, and dominated by ferns.
- Wetland: areas dominated by waterlogged soil.
- Bamboo: areas dominated by *Sinarundinaria alpina*.
- Mixed Bamboo forest: areas of bamboo intermixed with other forest species.
- Savanna: areas of at least 20m radius dominated by grassland.
- Shrubs: areas of shrubs less than 12m high, without trees.

(3) Record and mark chimpanzee nest: all nests observed from transect were recorded and marked and perpendicular distance from transect to the nest measured. Nests were classified into three age categories:

i. Fresh: all leaves in the nest are green and generally feces or urine odors were underneath the nest;

ii. Dry: leaves mostly dry with different color but still intact

iii. Old: nest with holes showing few or no leaves, but still identifiable by bent twigs

iv. Very old: leaves dead and often holes in the nest cup

(4) Animal and Human signs: all animal signs (dung) for bushpig, carnivores, and duiker observed was recorded, as well as human signs including snares, mining, trails, fire places, camps, beehives and encountered people. The perpendicular distance from transect to the sign was measured and the recorded sign was destroyed to avoid double counting on the next visit.

(5) Direct observation of animal: all animals observed were recorded as well as the perpendicular distance was measured from the transect to the center of the group or to the individual observed.

Camera trapping

Camera trapping is an increasingly popular survey tool widely used to study wildlife. This tool is generally regarded as non-invasive, and it can gather information on a range of species simultaneously and continuously over large survey areas and for several months at a time. WCS started using camera traps in 2008; however camera traps were opportunistically deployed in the park where staff were working and where signs of animals were seen and they were not deployed systematically in the 2009 survey.

During the 2014 biodiversity survey, camera traps were deployed throughout the park, following the transect design. In this survey, three types of digital camera traps were used: Reconyx hyperfire (HC500 and PC800 models), Reconyx rapidfire (RM45 model) and Bushnell (119437 model). To maximize the quality of images, their settings were harmonized, adapted from the Tropical Ecology Assessment and Monitoring (TEAM) Network protocol on Terrestrial Vertebrate Monitoring published by Conservation International in 2011. Camera traps were set at the beginning and the end of each transect focusing on shy and nocturnal species with emphasis on carnivores, ungulates and terrestrial birds that are not frequently captured in transect monitoring (duiker, bush pigs, carnivores, etc.). The figure below (Figure 2) shows the location of the seventy-eight points where camera traps were set. Due to problem of camera traps that failed to work during testing before the first deployment, no camera trap was deployed at transect 8 and

only one camera trap was deployed at transects 18 and 41. Each camera trap spent a minimum of 40 days at each location and the memory card and batteries were changed before relocation.

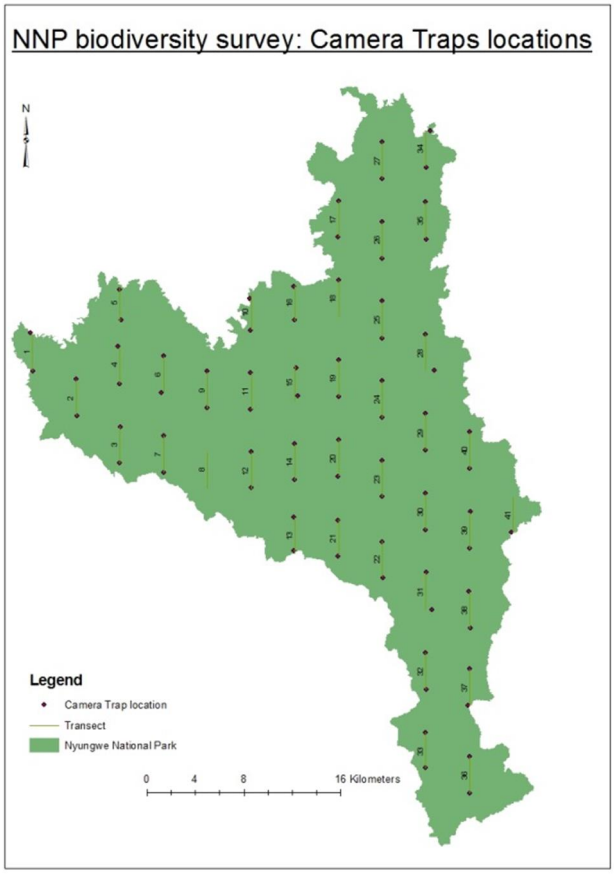


Figure 2. Location of camera traps

Each camera trap was set within 50 meters radius from the start or end point of transect. In this radius, the field team chose a site with animal signs such as trails and paths to water that animals use on a regular basis and with a good chance of animal visitation. A walk test was performed to determine the camera sensorôs range. After the walk test, each camera was placed at least 2 meters from the animal trail to maximize the quality and number of images. Camera traps were fixed on a tree with a good view to the animal trail at 50 cm off the ground and parallel to it. The chosen trees were with trunks that are reasonably straight, thin enough to tie the cable lock around, but not so thin that wind, people, or other animals can shake. Camera traps were also set pointing the direction of North or South to minimize direct sunlight exposure. Big leaves and tree branches between the camera trap location and the animal travel path were cleared as needed to maximize detection within the field of view of the camera trap.

Images were uploaded to Open DeskTeam and annotated. After processing, data were exported to a compressed file (TPK) that can be easily opened in excel. Data were analyzed by Dr. Tim OôBrien using species occupancy and density methods. PRESENCE 6.2 was used to perform Occupancy analyses on species for which there was sufficient data.

Data analysis

Line transect distance sampling, analyzed with Distance 6 (Thomas et al., 2009), was used to estimate densities of species with Ó60 observations. For all other animals that could not reach the required number of observations to obtain a good fit to the drop off in detectability with perpendicular distance (Ò60 observations), only encounter rates were calculated.

Density estimates of bushpig, duikers and chimpanzees were estimated from indirect signs. The density of individuals was obtained by removing all duiker and bushpig dung or marking chimpanzee nests on the first survey and then estimating detection functions for all the new dung piles or nests recorded on subsequent traverses of the transects. This method negated the need to estimate sign decay rates. The estimated new sign density was then corrected by the estimated production rate of signs and by the time between the first and last traverse of transects. Production rates of dung and nests were taken from literature, with a chimpanzee nest production rate of 1.1 per day (Plumptre & Cox, 2006; Morgan et al., 2006; Plumptre & Reynolds, 1996), duiker dung production rate of 4.4 dung piles per day (Plumptre & Harris, 1995) and bushpig dung production rate of 7 per day (McNeilage *et al.* 1998).

For the analysis of chimpanzee nests, the mean time period between subsequent surveys was 19 days and to be conservative, densities were calculated based on recorded fresh and dry nests only for the first repetition of data collection as old nests were presumed to have been made prior to the previous survey of the transect.

For all density estimates, to improve detection model fit, data were truncated and grouped into distance intervals to overcome problems of heaping. Model selection was based on minimizing Akaikeôs information criterion (Burnham & Anderson, 2002) and the results of the c2 goodness-of-fit test were also considered. The density of observations was multiplied by the surface area of the main forest block of Nyungwe National Park, (1,015km^2) excluding the fragmented forest of Cyamudongo (4km^2) which is part of the Nyungwe National Park to obtain the corresponding population estimates.

RESULTS

The total transect distance covered for the 2009 survey was 492km, with length of each of the forty one transects equal to 3km while in 2014 a distance of 663km was covered with average length of transect

equal to 3.235km.The most common estimator used to assess the density of animals, particularly mammal density from line-transect surveys, is the distance sampling method, as Buckland et al. (2001) delineated via Distance. We used line-transect distance sampling method to estimate the densities of *Pan troglodytes schweinfurthii, Cercopithecus mitis, Cercopithecus lhoesti, Potamochoerus larvatus, Funisciurus carruthersi, Heliosciurus ruwenzorii, Paraxerus boehmi* and all duiker species recorded during the survey. Considering that the team during the survey could not distinguish different species of duiker from their dung, we combined all sightings of duiker dung as ódukerô

SPECIES RICHNESS

During the 2009 - 2014 line transect surveys, a total of 20 species of medium and large mammals and carnivores were recorded, with 13 species recorded in 2009 and 16 species in 2014, of which half were primate species. In 2014, data was also collected on squirrels, a commonly targeted species by snaring; 6 different squirrel species were recorded (Table 1).

Table 1 Species observed during the 2009 and 2014 surveys.

Order	Species	2009*	2014
Primates	***Cercopithecus Ascanius***	**x**	**x**
	Cercopithecus lhoesti	**x**	**x**
	Cercopithecus mitis	**x**	**x**
	Cercopithecus mona	**x**	**x**
	Cercopithecus hamlyni	**x**	
	Colobus angolensis	**x**	**x**
	Lophocebus albigena	**x**	**x**
	Pan troglodytes	**x**	**x**
Even-toed ungulates	***Cephalophus silvicultur***	**x**	
	Cephalophus nigrifrons	**x**	**x**
	Tragelaphus scriptus	**x**	
	Potamochoerus larvatus	**x**	**x**
Carnivores	***Genetta tigrina***		**x**
	Canis adustus	**x**	
Rodents	***Funisciurus carruthersi***		**x**
	Funisciurus pyrropus		**x**
	Heliosciurus ruwenzorii		**x**
	Paraxerus alexandri		**x**
	Paraxerus boehmi		**x**
	Protoxerus stangeri		**x**
	Total species observed	**13**	**16**

**2009 Survey concentrated on medium-large mammal, no data on squirrels' observations were recorded.*

Map of mammal species richness along the 41 transects was done (Figure 3.4). Three species endemic and near endemic to the Albertine Rift (whose ranges are almost, but not entirely, restricted to the Albertine Rift) were

observed: the Albertine Rift endemic Ruwenzori sun squirrel (*Heliosciurus ruwenzori*), and the two species near endemic to the Albertine Rift, lôhoestiôs monkey (*Cercopithecus lhoestiI)* and the owl faced monkey (*Cercopithecus hamlyni*).

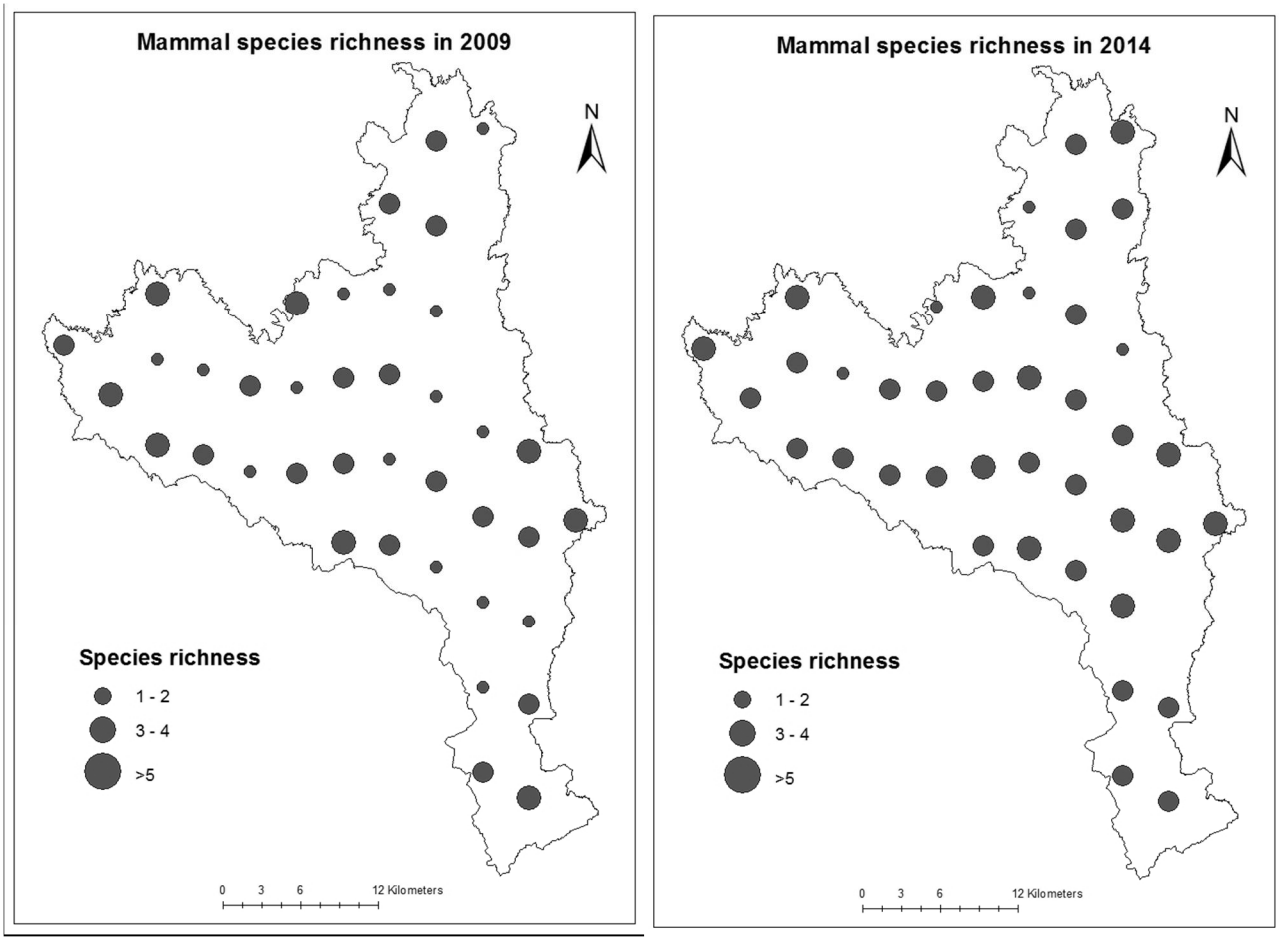


Figure 3.4. Mammal species richness at the 41 transects surveyed

In 2009, mammal species richness was higher in western and central part of the park (Gisakura, Uwinka, Kitabi, Bweyeye and Gasumo) while in 2014 the eastern and central part of the park seems to show high mammal species richness, while on both years the southern part of the park seemed to have the lower species richness.

PRIMATE ENCOUNTER RATES AND DENSITY

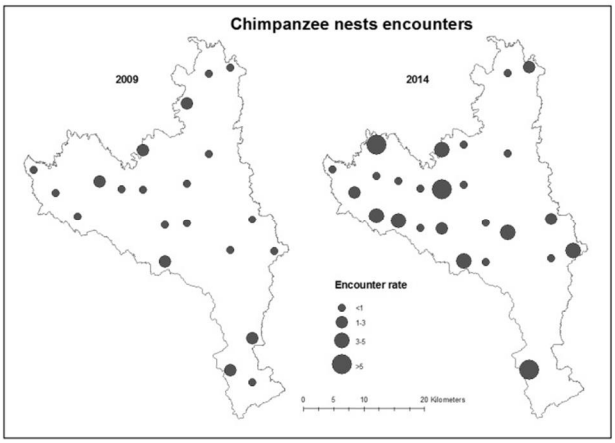
During the line transect surveys, the teams recorded more direct observations of primates group and individual counts in 2009 (N.gr= 124, N.ind=2350) compared to 2014 (N.gr= 120, N.ind=1000), despite that the length covered in 2014 (663km) was higher than the length surveyed in 2009 (492km). However, for most species the number of group observations was too low (Table 2) to allow comparisons between the two surveys (all except blue monkeys in 2009 had less than 20 group sightings while in 2014 all except blue monkeys and lôhoestiôs monkeys had less than 20 group sightings). For the two species with most group observation, blue monkeys (*C. mitis*)

experience a significant reduction in encounter rates of both groups and total individual counts through time, while the opposite was true for L'hoesti's monkey (*C. lhoesti*), although the increase was not significant.

Table 2. Encounter rates of direct observations of groups and individual primates (and nest sites for chimpanzees). The value in **bold** shows significant (P<0.05) and trend (P<0.1)

Species	2009				2014				Z-test		P-value	
	(N) Gr	(N) Ind	Gr	Ind	(N) Gr	(N) Ind	Gr	Ind	Gr	Ind	Gr	Ind
Cercopithecus ascanius	2	8	0.004	0.016	1	12	0.002	0.018	-0.816	0.056	0.21	0.519
Cercopithecus lhoesti	16	71	0.033	0.144	34	129	0.051	0.195	1.26	0.714	0.9	0.761
Cercopithecus mitis	61	450	0.124	0.915	53	222	0.08	0.335	-1.78	-2.577	**0.04**	**0.005**
Cercopithecus mona	4	86	0.008	0.175	2	19	0.003	0.029	-1.187	-1.394	0.12	**0.082**
Cercopithecus hamlynii	1	3	0.002	0.006	0	0	-	-	-	-	-	-
Colobus angolensis	13	1371	0.028	2.886	7	524	0.011	0.79	-1.579	-1.636	**0.06**	**0.051**
Lophocebus albigena	16	262	0.033	0.533	14	65	0.021	0.098	-0.683	-2.055	0.25	**0.02**
Pan troglodytes	11	50	0.022	0.102	9	29	0.014	0.044	-0.985	-1.226	0.84	0.112
Pan troglodytes (nest)	107	118	0.870	0.959	243	264	1.833	1.991	2.547	2.539	0.99	0.99

For chimpanzees, indirect observations (Nests) were also collected: from 2009 to 2014 there was an increase of encounter rate for both groups and individual nest counts (Table 2). Comparisons have been made on the distribution of different species at Nyungwe National Park by mapping the encounter rate on each transect (Figure 5.6). Mapping of the distribution of chimpanzee, duiker, bush pig and carnivores was based on encounter rates of signs.



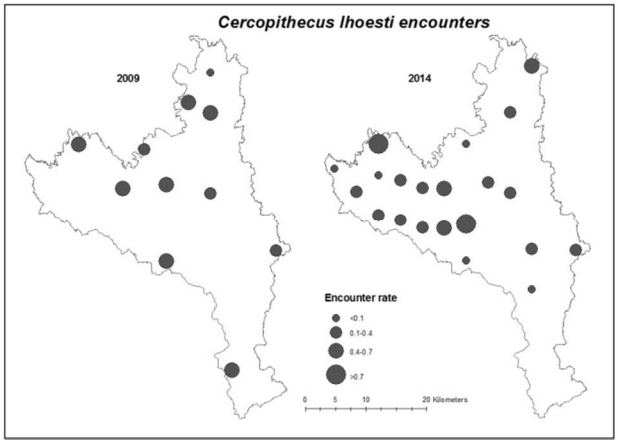


Figure 5.6. *Maps showing encounter per km of chimpanzee nest and direct observation of L'hoesti's monkey*

The maps above (Figure 5.6) show that there have been more observations of chimpanzee and lôhoesti monkey in 2014 compare to 2009 and both species are scattered in the whole park but with a bit more high encounters in the western part of the park. Signs of chimpanzees (excluding nests) were found at all 13 sites, most often in the western portion of the park.

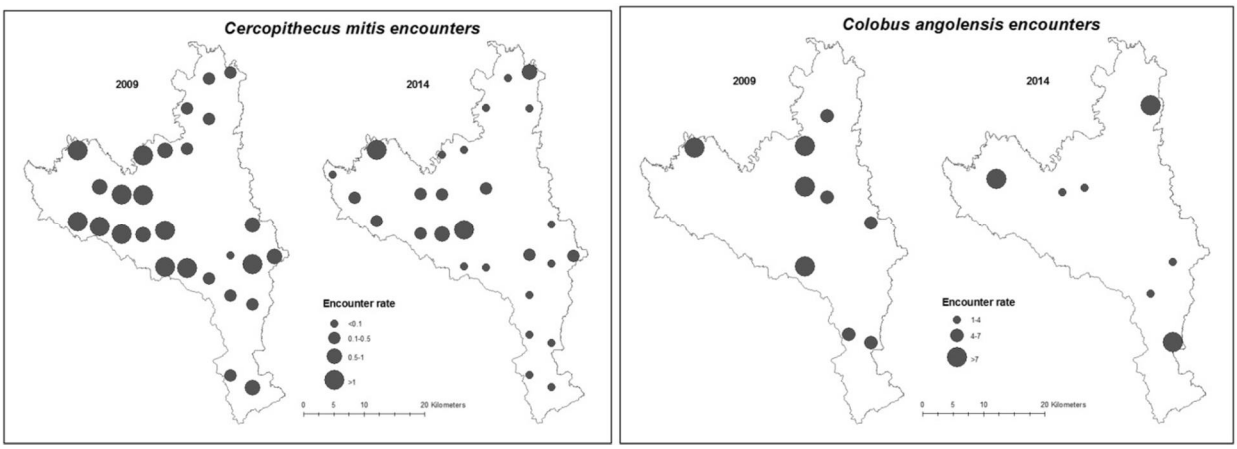


Figure 7.8. *Encunter rate distribution of Cercopithecus mitis(left) and Colobus angolensis (right) in NNP*

Signs of blue monkeys (*Cercopithecus mitis*), lôhoestiôs monkeys (*Cercopithecus lhoesti*) and colobus monkeys *(Colobus angolensis*) were found scattered across the park with overall less observations in 2014 and few observations of colobus in south-westen and central part of the park (Figure 6,7,8).

Distance sampling requires at least 60 observations to model a detection function consistently and to obtain a reliable estimate of density (Buckland et al., 2001). For direct primate observations, this was only possible for blue monkeys and lôhoestiôs monkeys. Density estimates of bushpig, duikers and chimpanzees were estimated from indirect signs. Nest density was converted to chimpanzee density by dividing nest density by average time between the first data collection to the last repetition of the data collection and by the number of nest production rate per day which is 1.1 nests per day (Plumptre and Rynolds 1996, Plumptre & Cox, 2006; Morgan et al., 2006). For blue monkey species, the density estimates decreased from 10.2 individuals/km^2 (95% CI, 6.37-16.37) in 2009 to 4.37 individuals/km^2 (95% CI, 2.59-7.38) in 2014 (Table 5), resulting in a significant drastic population reduction, from an estimated blue monkey population of 10,371 in 2009 to a population of 4,444 in 2014. For lôhoestiôs monkey the trend was reversed, with density estimates increased from 1.76 individuals/km^2 (95%CI, 0.75-4.12) in 2009 to 3.58 individuals/km^2 (95% CI, 2.03-6.30) in 2014 (Table 5), resulting in a population increase, from an estimated 1,788 in 2009 to a population of 3,638 in 2014.

Chimpanzee density estimate using nest counts was based on the observed fresh and dry nests recorded along the 41 transects, during transectsô revisits (4 revisits totaling 492 km surveyed in 2009, 5 revisits totaling 663km surveyed in 2014). In 2009, a total of 351 chimpanzee nests were observed during the entire survey. The density of chimpanzee was calculated based on the 186 observed fresh and dry nests recorded from the 1st to the 4th surveys

repetition and any old nests recorded from the 2nd to the 4th repetition along the 41 transects. In 2014, a total of 536 nests were recorded while the density was calculated based on 243 fresh and dry recorded from the 1st to 5th repetition and any old nest recorded from 2nd to 5th repetition. The Hazard-rate cosine model fitted well to the data in 2009 while in 2014 Half-normal cosine model fitted well and the selection of best model was based on the smallest Akaike Information Criteria (AIC). Nest density estimates formed the basis to derive chimpanzee density and population size from the best-selected model. Overall, the Nyungwe chimpanzee population appeared rather stable. In 2009, chimpanzee density was calculated as 0.42 weaned individuals/km^2 (95% CI, 16.1-48.43) with an estimated population of 430 chimpanzees in Nyungwe National Park while in 2014, chimpanzee density was 0.400 weaned individuals/km^2 (95% CI, 18.76-63.78), with an estimated population of 407 chimpanzee at Nyungwe National Park. Additional to this chimpanzee population of Nyungwe, we can add 35 to 50 chimpanzees that are in the fragmented Cyamudongo forest which was not covered during the 2009 and 2014 survey.

DUIKER, BUSH PIG, CARNIVORE ENCOUNTER RATE AND DENSITY

Due to the inaccuracy of determining different species from dung, all species of duikers and carnivores were lumped together respectively. Encounter rates and densities estimates were calculated through the observation of ónewô dung, during each transectsô revisits. For both duikers and bush pigs, the encounter rates were higher in 2014 than in 2009. For Carnivores, the encounter rates were higher in 2009 than in 2014. However, none of these trends were statistically significant.

Table 3. Encounter rate of indirect signs of Duiker, Bush pig and carnivores

Species	2009		2014		Z-test		P-value	
	Group	Individual	Group	Individual	Group	Individual	Group	Individual
All duiker species (dung)	0.12	0.14	0.8	0.87	1.96	1.96	0.975	0.975
Bushpig (dung)	0.07	0.1	0.79	0.98	2.67	2.69	0.996	0.996
All carnivore (dung)	0.1	0.12	0.08	0.08	-0.63	-0.92	0.264	0.178

During both years, duiker dung and Bush pig dung were more concentrated in the Eastern part of the park compared to other areas of the park. Many records of indirect signs of duiker and bush pig were observed in 2014 in Kitabi and Musebeya zone. No observation of duiker and bushpig was recorded in western (Gisakura, Gasumo and big area of Bweyeye).

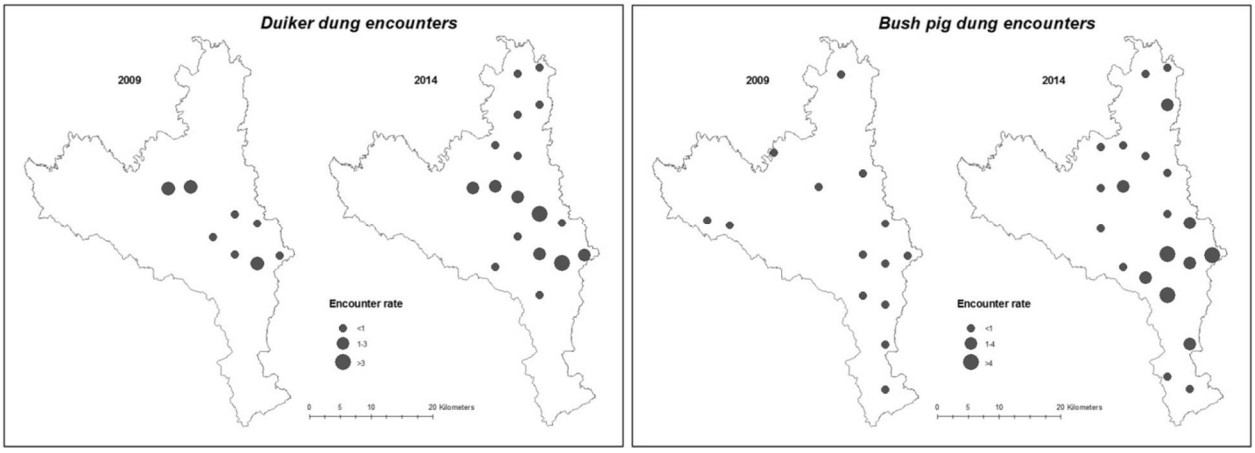


Figure 9.10. *Encounter rate distribution of Duiker(left) and Bush pig dung (right)*

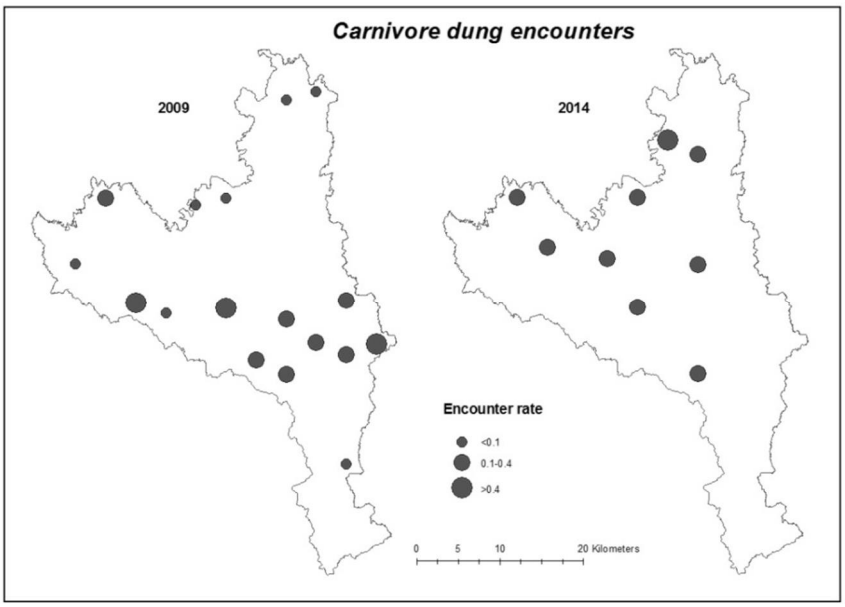


Figure 11: Encounter rate distribution of carnivore dung

Carnivores were most often detected by their dung. The only carnivore observed directly in 2009 was a jackal (*Canis adustus*) in the western part of the park (Gasumo) and in 2014 only a genet (*Genetta tigrina*) was observed directly near Gahurizo. Carnivores for which dung were believed to have been found included servals, genets, jackals, and mongooses, though these identifications could not be made with certainty. Since carnivores are often difficult to distinguish from one another by their dung, they have been lumped together (Figure 11) under the general category of carnivores. Evidence of carnivores was found mostly in center of the park in 2009 (Figure 11) while in 2014 their evidence were a bit scattered in the north; center and north-western area of the Park.

We used PRESENCE 6.2 to perform Occupancy analyses on the distribution of dung (Table 4). All analyses considered detection probability to be constant or a function of local abundance, and considered occupancy to be either constant across transects or a function of the same covariates used in the relative abundance correlation analysis. As a first step, we evaluated whether a simple null model with constant detection probability provided a

better fit than a Royle-Nichols abundance-induced heterogeneity model. Once we decided on the treatment of detection probability, we evaluated the effects of covariates on occupancy using single season occupancy models. All covariates were calculated as a mean of values at each observation on transect. If there were no observations made on transect, then the midpoint was used to characterize transect. Covariates used in the analyses included: distance from edge of the forest (Edge), distance from road (Road), habitat type (Hab), elevation (Elev).

Table 4. Occupancy results for duiker and bushpig dung on Line transects in 2009 and 2014.

Species	Year	Top Model	Obs_psi	Est_psi	Improvement	LCL	UCL	Lambda
Bushpig	2009	RN*(Edge -, Road +)	0.3171	0.429	35%	0.195	0.713	0.696
	2014	RN*(Elev +, Road +)	0.4878	0.674	38%	0.372	0.891	1.671
Duiker	2009	RN*(Road +,Hab, Elev +)	0.1951	0.1997	2%	0.072	0.412	0.259
	2014	RN*(Elev +, Edge +)	0.4146	0.483	16%	0.277	0.683	0.926

*RN: Royle-Nichols heterogeneity model

Detection probability for Bushpig and duiker dung was affected by local abundance (Table 4: lambda). Local abundance increased from 0.7 to 1.67 for bushpig and from 0.26 to 0.93 for combined duiker species.

Occupancy values for bushpig were affected by distance to the nearest road for both 2009 and 2014 (Occupancy increased with increasing distance from roads). Occupancy was negatively affected by distance to forest edge (higher occupancy values closer to the forest edge) in 2009 and positively affected by elevation (higher occupancy at higher elevation) in 2014. Occupancy values for combined duiker species were positively affected by elevation (higher occupancy at higher elevation) in both 2009 and 2014. Duiker occupancy was positively affected by distance to roads (higher occupancy with increasing distance from roads) in 2009 and by distance to forest edge (higher occupancy with increasing distance from forest edge) in 2014. In 2009, there was a difference in occupancy in short forest versus tall forests. Duiker dung was more widespread in short forests (psi=0.328) than in tall forest habitat (psi=0.121).

Estimates for duikers densities and encounter rates were calculated through the observation of ónewô dung, during transectsô revisits. All species were lumped together due to the inaccuracy of determining different species from dung (Table 5).

For 2009, we calculated the density based on signs recorded during the 1st to the 4th repetition of transects, while in 2014, we considered signs recorded during the 1st to the 5th repetition. Truncation and binning of observations into distance intervals helped to reduce effects of heaping and improve model fit. Densities were calculated at 0.98 bushpigs/km^2 (95% CI, 21.3ï 163.7) in 2009 while in 2014 were 0.69 bushpig/km^2 (95% CI, 19.8-86.5), and 0.85 duikers/km^2 (95% CI, 17.4-149.8) in 2009 while in 2014 there was 1.04 duiker/km^2 (95% CI, 25.3-265.8). These densities translate into a decrease in population size for Nyungwe bush pigs (from 981 in 2009 to 703 in 2014) and an increase in duiker population (from 867 in 2009 to 1,062 in 2014). These differences in densities through years were not statistically significant.

SQUIRREL ENCOUNTER RATE AND DENSITY

Different species of squirrel were recorded in 2014 survey including the Carruther's Mountain Squirrel *(Funisciurus carruthersi),* the Fire-footed Rope Squirrel *(Funisciurus pyrropus),* the Ruwenzori Sun Squirrel *(Heliosciurus ruwenzorii),* the Alexander's bush squirrel *(Paraxerus alexandri)*, the Boehm's bush squirrel *(Paraxerus boehmi)* and the forest giant squirre *Protoxerus stangeri.* In 2009, observers were not required to record squirrelsô observations among data to be collected. Most of the species of squirrel are distributed across the whole park (Figure 12, 13, 14) with higher encounter rates recorded in the center of the park and fewer observations made in the south of the park for the Ruwenzori sun squirrel.

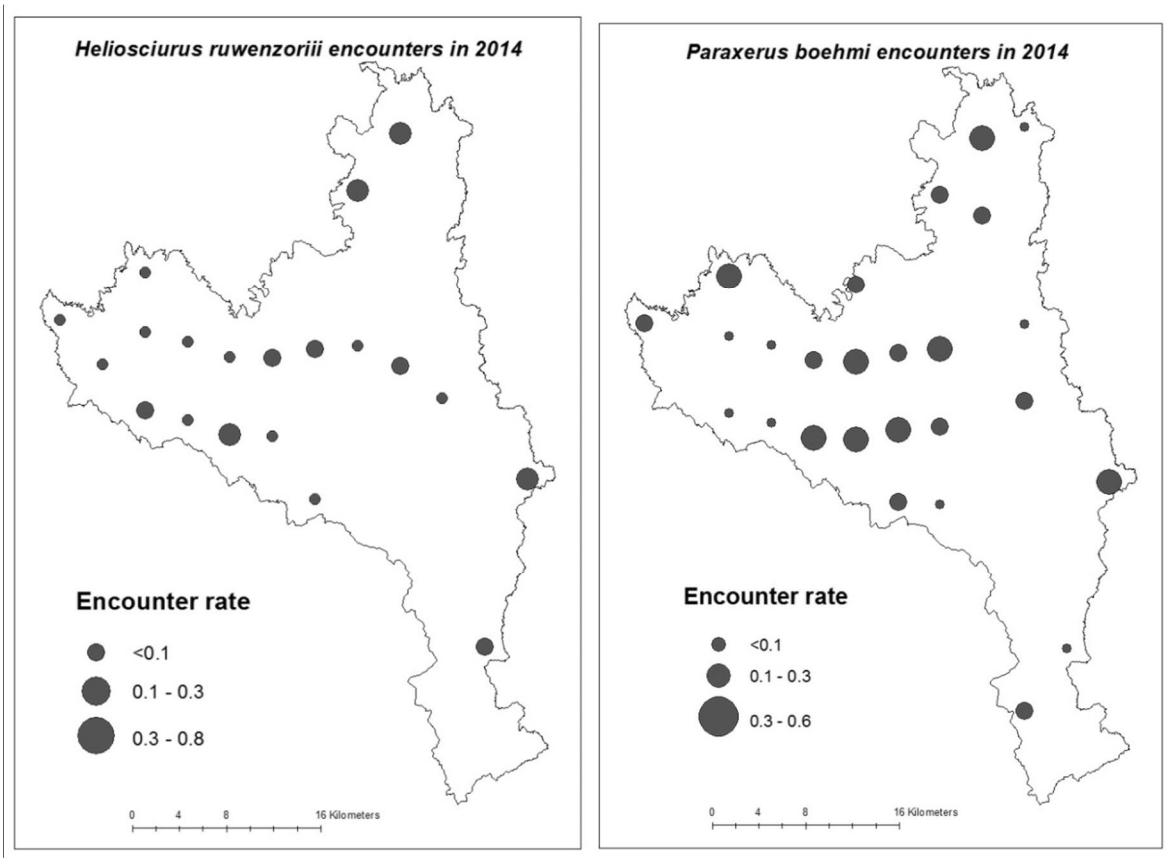


Figure 12 and 13. Encounter rate distribution of squirrels (*H.ruwenzorii* and *P.boehmi*) in 2014 survey

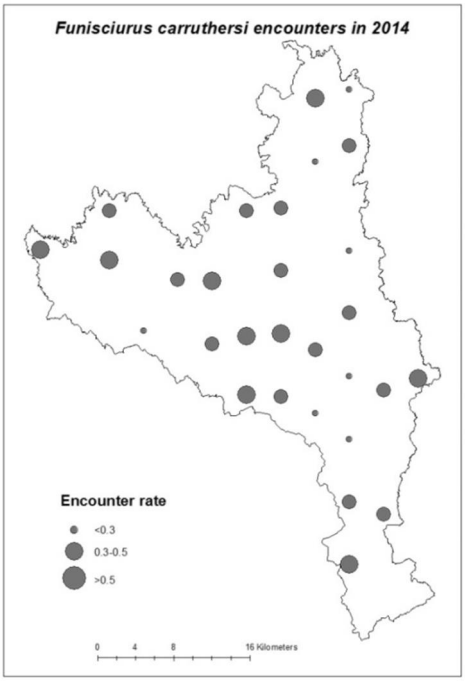


Figure 14. Encounter rate distribution of *Funisciurus carruthersi* in 2014 survey

The density estimate of three different species of squirrel mentioned above was calculated, as they were the only species for which at least 60 observations were recorded. Due to low numbers of direct observations, a density estimate calculated from direct observation was only possible for Carruther's Mountain Squirrel, Ruwenzori Sun Squirrel, Boehm's bush squirrel and blue monkeys. The density estimate of Carruther's Mountain Squirrel was 9.2 (95% CI, 6.5-13.3) with a population of 9,459 at Nyungwe, Ruwenzori Sun Squirrel density was 2.2 (95% CI, 1.3-3.9) with a population estimate of 2,281 at Nyungwe and the density of Boehm's bush squirrel was estimated at 4.1 (95% CI, 2.7-6.3) with a population estimate of 4,194 in Nyungwe National Park.

Table 5. Average density of mammal species recorded during the 2009 and 2014 survey with number of observation Ó60

Species	2009	2014	Z-test	P-Value
Cercopithecus lhoesti	1.761	3.58	1.404	0.919
Cercopithecus mitis	10.22	4.378	-2.14	**0.016**
Duiker	0.853	1.05	0.708	0.758
Bush pig	0.987	0.692	-0.497	0.312
Pan troglodytes	0.424	0.4	0.503	0.691
Funisciurus carruthersi	-	9.283	-	-
Heliosciurus ruwenzorii	-	2.238	-	-
Paraxerus boehmi	-	4.115	-	-

SMALL MAMMALS SPECIES DIVERSITY

In 2009, small mammals were surveyed in different sites. Six sites were considered including: Gisakura, Bigugu, Bweyeye, Nyabishwati, Gasare and Cyamudongo. The numbers of trap-lines at each site varied according to the amount of time spent at each site. Four trap-lines were established at Gisakura, 10 at Bigugu, 12 at Bweyeye, 8 at Nyabishwati, 5 at Gasare, and 3 at Cyamudongo. A total of about 630 specimens of small mammals were collected and exported to the Field Museum of Natural History for preparation, further identification and cataloging.
Three types of traps were used: small Victors, big Victors and Museum Specials while most of shrews were captured in pitfalls and different preparation were done for each specimen including the Skin, Skeleton, Skull and fluid preparation.

Thirteen species of small mammals were recorded for the first time in the Nyungwe National Park (Table 6). The new species documented were scattered at different elevation, two were found at the lowest elevations (Hylomyscus aeta and Hylomyscus stella), one was found at the highest (Praomys degraaffi, Mt Bigugu), one was fairly widespread (Grammomys sp.) and one was confined to a middle elevation swamp (Dasymys sp.).

Table 6. List of rodents recorded at Nyungwe by elevation

Genu	Elevation / Species	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	New Record for the Park
Hybomys	*sp*	1	16	2	6	8		1		1*	5					No
Hylomyscus	*vulcanorum*	1	1				7			1*		1	3		1	No
Lophuromys	*aquilus*	9	37	10	10*	11*	3*	*	8*	*	*	9	4	1	18	No
Mus	*bufo*	1	7	3	1	4		*	1	*						No
Oenomys	*hypoxanthus*	1	3		1	1		*		*		2				No
Praomys	*jacksoni*	1	20	30	16	12*	22*	11*	*	*	*					No
Colomys	*goslingi*		3				4			*						No
Deomys	*ferrugineus*		2							*						No
Funisciurus	*carruthersi*		1			1				*	*			1		No
Hylomyscus	*aeta*		3													**Yes**
Hylomyscus	*stella*		15				5									No
Malacomys	*longipes*		23		1*	1	7			*						No
Praomys			1			1		1								
Thamnomys	*kempi*		2				2	1		*	*					No
Grammomys	*sp*			1		6							2	1	4	**Yes**
Graphiurus	*sp*			1^												**Yes**
Lophuromys	*woosnami*			4	3	7	6	*	8*	4*	2*	17	14	8	47	No
Mus	*musculoides*			2				*								No
Mus	*sp*					1										?
Paraxerus	*boehmi*					1				*						No
Lophuromys	*luteogaster*				*		1									No
Lophuromys	*rahmi*					*	2*	*	*	*						No
Hylomyscus								1								?
Dasymys	*sp*								4							**Yes**
Dendromus	*nyasae kivu*								1	*						No
Otomys	*denti*				*	*	*	*	1*	*						No
Praomys	*degraaffi*											3	14	1	17	**Yes**
Delanymys	*brooksi*							*					1			No
Otomys	*tropicalis*									*					1	No

^ collected outside the Park at Gisakura

* present in Dowsett survey collection

The small mammal survey recorded 8 new species of shrew to the park list which includes *Crocidura dolichura, C. niobe, C. sp. indet., Myosorex babaulti, Suncus hututsi, S. megalura, and Sylvisorex johnstoni* and one otter shrew (*Micropotamogale ruwenzorii*), therefore doubling the list from 10 to 18. Furthermore, with the exception of *Suncus megalura* and perhaps *Crocidura sp*. (undetermined), all of these shrew species are new records for the entire country. This is also the first record of the otter shrew outside of the Eastern Democratic Republic of Congo and hence the first record for East Africa. Overall, we added nearly 50% new species to the known terrestrial small mammal list for the park (from 34 to 47 species).

Table 7. List of shrews recorded at Nyungwe National Park by elevation

Genus	Species	1600	1700	1800	1900	2000	2100	2200	2300	240	2500	260	2700	2800	2900	New Record for the Park
Crocidura	*dolichura*	1	1												1	**Yes**
Crocidura	*maurisca*"	1							1							No
Suncus	*hututsi*	3														**Yes**
Sylvisorex	*lunaris*	1	1							*			2	1	3	No
Sylvisorex	*vulcanorum*	2	2				3			*				1	7	No
Suncus	*megalura*		1													**Yes**
Sylvisorex	*johnstoni*		1		1											**Yes**
Crocidura	*olivieri*		4		2*		3*	1*	2*	*	*	3	1			No
Crocidura	*sp*		1													**Yes**
Micropotamogale	*ruwenzorii*						1									**Yes**
Crocidura	*lanosa*						2			*						No
Crocidura	*niobe*												1			**Yes**
Myosorex	*babaulti*												1		1	**Yes**
Chrysochloris	*stuhlmanni*									*					1	No

* present in Dowsett survey collection

"present in Kityo collection

HUMAN SIGNS

Threats to Nyungwe include poaching, mining, fires, bamboo cutting, tree harvesting for firewood and house construction, livestock grazing, all exacerbated by the lack of alternative income-generating opportunities which contribute to the ongoing exploitation of the forest resources. Most observations of human sign during the 2009 and 2014 surveys belongs to the following categories: wood cutting, snares, people and mining sites. A general category of ñotherò included more rare observations such as sawing, poachersô camps, agriculture cultivation etc. (table 6). Overall, there was a sharp increase in encounter rate of human signs from 2009 to 2014.

Table 6. Encounter rate of human signs during the surveys

Human sign	2009 survey (492km)		2014 survey (796km)	
	Obs	Enc rate	Obs	Enc rate
Wood cutting	8	0.016	18	0.023
Snares	3	0.006	40	0.050
People	-	0	7	0.009
Mining sites	-	0	9	0.011
Fires	-	0	3	0.004
Other	8	0.016	8	0.010

Total	**19**	**0.038**	**85**	**0.107**

The encounter rate of human signs recorded in 2009 was 0.038 and 0.107 in 2014. Encounters of wood cutting (0.016 encounter km-1) was higher than any other human sign recorded in 2009 whereas snares encountered was higher in 2014 (0.050 encounter km-1).

A comparison was made between data collected on human signs from the survey and those recorded through the Ranger Based Monitoring, collected from May to September in 2009 where 3,411km were walked, and May to September in 2014 where 3,785km were walked by rangers (Table 6 & 7)

Table 7. Encounter rate of human signs during the ranger based monitoring data collection

(Only the most frequent human signs recorded during the survey were considered for comparison)

Human signs	**2009 (3,411km)**	**2014 (3,785km)**
Wood cutting	0.13	0.32
Snares	0.32	0.81
Mining sites	0.02	0.04
Total	**0.47**	**1.17**

With comparison to data collected by rangers through the RBM program, encounter rates of human signs were lower in line transects, with 0.038 signs/kilometer surveyed in 2009 than 0.47 sign/kilometer in RBM in 2009 and 0.082 signs/kilometer surveyed in 2014 than 1.17signs/kilometer for RBM in 2014. This comparison takes into account only the most frequent human signs recorded during the surveys. Overall, the two methods show consistency on their findings of an increase in the trend of human sign detection over time.

Correlation between mammal sightings and edge of the park, ranger post and roads

Spearman rank correlation coefficients were calculated to assess the influence of site accessibility (distance to park edge, roads and ranger post) on mammal sightings and illegal activitiesô encounters. Using ArcGIS 9.3, multiple ring buffers of 500m each were created for each of the three parameters (park edge, roads, and ranger posts). Sampling effort along transect in each buffer ring was defined as óthe number of metersô sampled in each buffer ring (sum of length of all transectsô portions passing in each interval of buffer ring). The total number of observations (illegal activities or mammal sightings) in each buffer ring was then divided by the sampling effort to generate effort-corrected observations that were used to calculate spearman rank correlation coefficients with distances to park edge, roads, and ranger posts.

Spearman rank correlations were used to investigate in 2009 and 2014 survey data, the relationship between mammal sightings and the edge of the park, roads inside the park and ranger post (Table 8, Table 9).

In 2009, both blue monkey and mangabey showed significant negative correlations to the edge of the park; none of the mammals showed significant correlation to the roads in 2009 while only blue monkey showed a significant negative correlation to distance to ranger posts.

Table 8. Spearman rank correlation between mammal sightings and park edge, roads, ranger post in 2009. Correlation coefficient in **bold** are significant

	Spearman rank -park edge-	Spearman rank –roads-	Spearman rank -ranger post-
Cercopithecus ascanius	-0.104	-0.280	-0.099
Duikers*	0.484	-0.298	0.315
*Pan troglodytes**	-0.430	0.082	-0.389
Cercopithecus lhoesti	-0.238	0.109	-0.426
Cercopithecus mitis	**-0.512**	-0.086	**-0.591**
Cercopithecus mona	-0.472	-0.182	0.018
Colobus angolensis	-0.202	-0.221	-0.298
Lophocebus albigena	**-0.758**	-0.301	-0.161
*Potamochoerus larvatus**	-0.144	-0.278	0.204

*We considered direct and indirect observation

In 2014, the blue monkey (-0.688), Mangabey (-0.577) and Ruwenzori Sun Squirrel (-0.510) were all significantly negatively correlated to the distance to the edge of the park (Table 9). This means that these three species of mammal showed a preference to be near the edge of the park. There were significant positive correlations (correlation coef.>0.5) between edge of the park and sightings of chimpanzee and bush pig. There is an apparent shift of *Pan troglodytes shweinfurthii* and *Potamocherus larvatus* from the park edge to deep inside the park (in 2014, they were more localized far inside the park than in 2009). Duikers, lôhoesti monkey, mangabey and Alexanderôs bush squirrel showed significant negative correlations to the roads, indicating they were more abundant near roads. Blue monkey showed significant negative correlation to the ranger post while bush pigs showed significant positive correlations to the ranger post, which does not give a clear indication of the role of ranger posts in protecting animal species.

Table 9. Spearman rank correlation between mammal sightings and park edge, roads and ranger post in 2014. Correlation coefficient in **bold** are significant

	Spearman rank -park edge-	Spearman rank -roads-	Spearman rank -ranger post-
Duikers	0.338	**-0.688**	0.442
Cercopithecus ascanius	-0.338	-0.178	-0.256
Cercopithecus lhoesti	0.002	**-0.564**	-0.309
Cercopithecus mitis	**-0.688**	0.224	**-0.663**
Cercopithecus mona	-0.338	-0.248	-0.281
Colobus angolensis	-0.172	0.014	-0.116
Lophocebus albigena	**-0.577**	**-0.555**	-0.249
Pan troglodytes	**0.538**	0.305	-0.197
Potamochoerus larvatus	**0.556**	-0.175	**0.614**
Funisciurus carruthersi	-0.033	0.268	-0.155
Funisciurus pyrropus	-0.002	0.231	-0.155
Heliosciurus ruwenzorii	**-0.510**	-0.202	-0.233

Paraxerus alexandri	-0.146	**-0.512**	0.046
Paraxerus boehmi	0.021	-0.119	-0.168
Protoxerus stangeri	-0.050	-0.416	0.255

*We considered direct and indirect observation

Correlation between human signs and edge of the park, ranger post and roads

The correlation between human signs and park edge, roads and ranger post has been calculated to estimate the relationship between these parameters and human signs.

Among the illegal activities that were observed in 2009, wood cutting was more frequent near the park edge, roads, and ranger posts; fire was more frequent near the park edges; snares were more frequent near the park edge, while other illegal activities including agriculture and poachersô huts/ camps were more concentrated far from roads and ranger posts (Table10). Agriculture and poachers camps are activities that indicate staying in the forest for a long period; therefore people doing them had to avoid ranger posts and roads so that they can stay many days in the forest and remain unseen.

Table 10. Spearman rank correlation (r) between human signs and distance to the park edge, roads and ranger post in 2009.Correlation coefficient in **bold** are significant

	Spearman rank -park edge-	Spearman rank – roads-	Spearman rank -ranger post-
Wood cutting	**-0.623**	**-0.628**	**-0.631**
Snares	**-0.983**	0.063	-0.104
Fire	**-0.568**	0.349	0.417
Others (Agri, Hut)	0.183	**0.673**	**0.504**

Table 11. Spearman rank correlation (r) between human signs and distance to the park edge, roads and ranger post in 2014. Correlation coefficient in **bold** are significant

	Spearman rank -park edge-	Spearman rank –roads-	Spearman rank -ranger post-
Wood cutting	-0.067	0.443	-0.202
Mining	-0.139	-0.276	0.222
Snares	**0.590**	0.150	0.138
Fire	0.302	-0.250	**0.505**
Others (hut, poachers)	-0.447	-0.256	-0.183

In 2014, snares were less abundant near park edges and increased when moving far from the edge into the forest; while fire increased as one moves far from the ranger posts and none of the human sign was significantly correlated to the road although wood cutting shows a positive trend of correlation to the road.

However, due to the very low numbers of observation recorded for human signs during the surveys, especially in 2009, the results from the correlations should be considered with caution.

CAMERA TRAPPING

We planned to deploy camera traps at the beginning and the end point of each of 41 transect but 11 cameras failed in the field due to poor setup (2 cameras), incorrect camera trap settings (1 camera) and unknown failures (8 cameras). In the end, we used images from 67 points, generating 25,303 photographs, including 11,203 photographs of wildlife over 2,565 trap-days. Species observed using camera traps included 11 bird species (1,795 photographs) and 23 mammal species (9,419 photographs: Table 12); adding 7 mammal species to what was found using the transect methodology in 2014

Table 12. Family, genus and species for 11 bird and 23 mammal species captured in camera traps. The * indicates species that were included in the Occupancy analysis.

Bird Family	**Latin binomial**	**Common Name**	**# Photographs**
Threskiornithidae	*Threskiornis aethiopicus*	Hadada Ibis	42
Phasianidae	*Francolinus nobilis*	Handsome francolin*	756
Phasianidae	*Francolinus squamatus*	Scaly francolin	18
Columbidae	*Turtur tympanistria*	Tambourine dove	731
Columbidae	*Streptopelia lugens*	Dusky turtle dove	77
Turdidae	*Alethe poliophrys*	Red-throated alethe	14
Turdidae	*Cossypha archeri*	Archer's ground robin	98
Turdidae	*Pogonocichla stellata*	White-starred forest robin	17
Turdidae	*Turdus olivaceus*	Olive thrush	27
Turdidae	*Zoothera tanganjicae*	Kivu ground thrush	9
Timaliiadae	*Pseudoalcippe abyssinica*	African hill babbler	6
Mammal Family			
Cercopithecidae	*Cercopithecus lhoesti*	L'hoest's monkey*	1501
Cercopithecidae	*Cercopithecus mitis*	Blue monkey	198
Cercopithecidae	*Colobus angolensis*	Angolan colobus	25
Cercopithecidae	*Lophocebus albigena*	Grey-cheeked mangabey	17
Hominidae	*Pan troglodytes*	Chimpanzee*	514
Hominidae	*Homo sapiens*	Human	256
Cricetidae	*Cricetomys gambianus*	Forest pouched rat*	1439
Sciuridae	*Funisciurus carruthersi*	Carruther's mountain tree squirrel*	505
Sciuridae	*Funisciurus pyrropus*	Cuvier's fire-footed squirrel	164
Sciuridae	*Paraxerus boehmi*	Boehm's squirrel*	787
Sciuridae	*Paraxerus alexandri*	Alexander's suirrel	2
Sciuridae	*Protoxerus stangeri*	African giant squirrel	9
Sciuridae	*Heliosciurus ruwenzorii*	Montane sun squirrel	3
Viverridae	*Genetta servalina*	Servaline genet*	223
Viverridae	*Genetta tigrina*	Blotched genet*	139
Viverridae	*Civettictis civetta*	African civet	3
Viverridae	*Nandinia binotata*	African palm civet	23
Procaviidae	*Dendrohyrax dorsalis*	Western tree hyrax	22

Canidae	*Canis adustus*	Side-striped jackal	32
Hystricidae	*Atherurus africanus*	Brush-tailed porcupine*	1157
Bovidae	*Cephalophus nigrifrons*	Black-fronted duiker*	1706
Bovidae	*Cephalophus silvicultor*	Yellow-backed duiker	58
Suidae	*Potamochoerus larvatus*	Bushpig*	625

We defined independent camera trap events using the criteria of OôBrien et al. (2003). Consecutive images of different species were considered independent events. Consecutive images of the same species taken more than 30 minutes apart were considered independent events and consecutive images of the same species in which the number of individuals increased were considered independent events. We used the number of independent events per 100 trap-days as an index of relative abundance (RAI). We also identified seven covariates that we believed might affect the relative abundance and distribution of wildlife species in Nyungwe NP (Table 13). Habitat was reduced to 3 classes (Open habitats, Short Forests, and Tall Forests) in order to have enough observations in each class. Elevation, Distance to road, distance to forest edge, distance to a ranger post, distance to the outer edge of the buffer zone and depth of the buffer zone were all considered. Elevation affects the distribution of some species as a biological covariate since elevation ranges are a characteristic of species. The distance measures serve as surrogates to access and hunting and can be considered anthropogenic covariates. All distance variables were converted to z-scores with a mean of 0 and a variance of 1 to ensure that all covariates covered similar ranges.

Table 13. Covariates used in occupancy analysis.

Covariate	Min/max (km)	Values
Habitat		Open Habitat = 0 Short Forest = 1 Tall forest = 2
Elevation	1.68/2.74	z-transformed z ~ N(0,1)
Distance to Road	0.011/28.61	z-transformed z ~ N(0,1)
Distance to Ranger Post	0.55/11.64	z-transformed z ~ N(0,1)
Distance to Forest Edge	0.042/10.22	z-transformed z ~ N(0,1)
Distance to Buffer Zone Edge	0.043/10.36	z-transformed z ~ N(0,1)
Buffer Zone Depth	0.00/3.24	z-transformed z ~ N(0,1)

We analyzed the RAI by correlating speciesô relative abundance with each covariate (Table 14). RAIôs were not systematically correlated with the covariates. Elevation was significantly and positively correlated with *F. nobilis* only. Distance to a ranger post was negatively correlated with *F. carruthersi* and positively correlated with *P. larvatus*. The depth of the buffer zone was positively correlated with *C. nigrifrons, C. gambianus*, and *A. africanus*. Because this is the first year that camera traps have been used, no further comparisons are possible.

Table 14. Correlation between species' relative abundance indices and covariates. * indicates a significance level of <0.05 and ** indicates P<0.01.

Species	Habitat	Elevation	Road	Ranger post	forest edge	buffer edge	buffer depth
F. nobilis	NS	0.307*	NS	NS	NS	NS	NS
F. squamatus	NS	NS	NS	NS	NS	NS	NS
C. nigrifrons	NS	NS	NS	NS	NS	NS	0.48**
C. silvicultor	NS	NS	NS	NS	NS	NS	NS
C. lhoesti	NS	NS	NS	NS	NS	NS	NS
C. mitis	NS	NS	NS	NS	NS	NS	NS
P. troglodytese	NS	NS	NS	NS	NS	NS	NS
C. gambianus	NS	NS	NS	NS	NS	NS	0.304*
F. carruthersi	NS	NS	NS	-0.24*	NS	NS	NS
P. boehmi	NS	NS	NS	NS	NS	NS	NS
A. africanus	NS	NS	NS	NS	NS	NS	0.269*
P. larvatus	NS	NS	NS	0.268*	NS	NS	NS

We used PRESENCE 6.2 to perform Occupancy analyses on species for which we had sufficient data (Table 12). All analyses considered detection probability to be constant or a function of local abundance, and considered occupancy to be whether constant across camera trap sites or a function of the same covariates used in the relative abundance correlation analysis (Table 14). As a first step, we evaluated whether a simple null model with constant detection probability provided a better fit than a Royle-Nichols abundance-induced heterogeneity model. Once we decided on the treatment of detection probability, we evaluated the effects of covariates on occupancy using single season occupancy models.

Of the 11 species evaluated, detection probability was affected by local abundance (Table 15: lambda) for 9 species. Occupancy models failed for Servaline genet due to few sites with replicated observations. A constant detection, constant occupancy model was chosen for the blotched genet, giving an estimated occupancy of 0.332.

Table 15. Number of photographs, Occupancy model, observed occupancy (Obs_Psi), estimated occupancy (Est_Psi), model improvement and point abundance (Lambda); RN indicates that the Royle-Nichols heterogeneity model is preferred for estimation of detection probability.

Species	N	Psi Model	OBS_Psi	Est_Psi	Improvement	Lambda
F. nobilis	756	RN(Elev+)	0.418	0.508	22%	0.777
C. nigrifrons	1706	RN(Elev+, Habitat)	0.388	0.455	17%	0.698
C. Lhoestsi	1501	RN(Elev+, Edge-)	0.582	0.667	15%	1.194
C. gambiensis	1439	RN(Post-)	0.567	0.629	11%	1.071
A. africanus	1157	RN(Road-, Buffdepth+)	0.463	0.529	14%	0.806
P. larvatus	625	RN(Elev+, Post-)	0.179	0.289	61%	0.391
P. troglodytes	514	RN(Edge-, Habitat)	0.224	0.267	19%	0.347
F. carruthersi	505	RN(Post-)	0.373	0.441	18%	0.604
P. boehmi	787	RN(Habitat, Road-, Buffdepth-)	0.164	0.225	37%	0.327

G. servalina	223	Failed	0.284	0.284	NA	NA
G. tigrina	139	psi(.),p(.)	0.167	0.332	99%	NA

Distance to forest edge had a negative effect (higher occupancy close to forest edge) for L'hoesti's monkey, Chimpanzee, and Bushpig. Distance to roads had a negative effect (higher occupancy closer to roads) for porcupine and Boehm's squirrel. Distance to a ranger post had a negative effect (higher occupancy closer to post) for Forest pouched rat and for Bushpig. The depth of the buffer zone had a positive effect on porcupine (higher occupancy associated with thicker buffer zone) and a negative effect for Boehm's squirrel.

Occupancy values for Black-fronted duiker, Chimpanzee and Boehm's squirrel were affected by Habitat class. Black fronted duiker tend to occur more in Tall forest (psi=0.56), followed by open areas (psi=0.45) and short forest (psi=0.33). Chimpanzee tend to occur more often in Tall forest (0.29), followed by Short forest (psi=0.26) and open areas (psi=0.23). These differences, though improving model fit, are not very great. Boehm's squirrel tend to occur more in Tall forest (psi=0.28), followed by short forest (psi=0.18) and open areas (psi=0.19).

DISCUSSION

Primate

Nyungwe Forest is renowned for its extremely high primate diversity, with 20% of African primates identified in the Forest (Vedder, 1988). Plumptre, et al. (2007) identified Nyungwe National Park as one of the highest ranking sites for conservation priority within the Albertine Rift. It protects two range-restricted primate species, the l'hoest's monkey and the owl-faced monkey. Both species are semi-terrestrial and Nyungwe has the only known population of owl-faced monkey within east Africa. The L'hoest's monkey and the owl-faced monkey are near-endemic species to the Albertine Rift. Both are classified as Vulnerable by the IUCN Red List of Threatened Species (IUCN, 2014).

During the 2009 and 2014 surveys 8 primate species were observed (Table 1). Two other species, Olive baboon (*Papio Anubis*), and Vervet monkey (*Cercopithecus aethiops*), are forest edge species, commonly found within the buffer zone or outside the main forest and were not observed in these surveys. An additional two (possibly three) species are nocturnal primates, not targeted in the surveys. The surveys observers recorded an overall decline in numbers of groups and individual primates encountered, with group numbers approximately the same (N=125 in 2009 and N=120 in 2014) while individual counts dropping to less than half from 2009 (N=2350) to 2014 (N=1000), despite the length of transects surveyed increased in 2014 (663km) compared to 2009 (492km). While this data is certainly worrying, there is also a possibility of observational bias, given the significant change in individuals counted within the groups. Unfortunately, data on individual primate species was often insufficient to understand the trends. For instance, in 2009 only for blue monkeys, there were more than 20 group sightings (and the same was true in 2015, with the exception of l'hoesti's monkey). For the three species for which it was possible to compare encounter rates and densities for the 2009 and 2014 surveys, l'hoesti's monkey, the blue monkey, and

chimpanzees (through nest counts) results differed in all three cases (respectively increasing, decreasing and staying stable between 2009 and 2014).

The population of L'hoesti's monkeys was found to have increased through time, with encounter rates of individuals as well as groups increasing from 2009 to 2014 and with an estimated population of 1,761 weaned individuals in 2009 doubled to an estimated population of 3,584 individuals in 2014. This is species commonly encountered in different type of habitats including short open forest and tall open forest and is typically observed along the Nyungwe road, crossing the middle of the forest.

The blue monkey (*C. mitis*) population, on the other end, experienced a drastic and significant decrease in time, in both group and individual encounter rates and a decrease in density, with an estimated population of 10,412 individuals in 2009 decreasing to estimated 4,461 in 2014. At this time, the causes for the drastic population decrease of blue monkeys in Nyungwe are not known. In fact, there is no evidence that this species was particularly targeted by hunters nor that it experienced a health outbreak, considering that WCS and RDB park staff regularly working in the forest would have encountered a number of carcasses in the occurrence of an epidemic.

The owl-faced monkey is one of the least known of the African cercopithecidae due to its terrestrial and secretive nature and restricted range. This species was first observed in Rwanda in 1989 in Nshili, in Southern Sector of Nyungwe National Park (Gibson, 1992). The 2009 survey included a single observation of this species which was recorded within a bamboo zone known to be a preferred habitat of the species while in 2014 survey although there was no direct observation during the transect data collection, one video observation was recorded with camera trap. However more detailed surveys of the bamboo habitat have found that within this preferred habitat encounter rates of owl-faced monkey are 0.081 groups per km (Easton et al, 2011) with an average of 22 individuals in one group (Ntare, 2007).

The 2009 density estimates of the eastern chimpanzee (0.424 weaned individuals per km^2) was comparable to the one calculated in the 2014 survey (0.400 weaned individuals per km^2), providing a population estimate of 432 chimpanzees in 2009 and 408 in 2014 in the main forest block of Nyungwe National Park. To these numbers one should add the estimated 30 semi-habituated chimpanzees of the Cyamudongo forest patch, which were not surveyed in this study but are part of Nyungwe National Park. These add up to ±460 chimpanzee population estimated in Nyungwe National Park, and the largest population of chimpanzee remaining in Rwanda. The density estimates of both surveys are comparable (if a slightly higher) than the previous estimate for which the chimpanzee population of Nyungwe was estimated at 382 individuals (Barakabuye, 2007), showing a rather stable population.

Ungulates and carnivores

The results for the mammal species recorded through indirect signs (dung of duikers, bushpigs and carnivore) show a somehow mixed picture, with duikers increasing, carnivores decreasing and bush pigs encounter rates increasing but density estimates decreasing in the 2009-2014 period.

Two duiker species (*Cephalophus nigrifrons* and *Cephalophus silvicultor*) were seen in 2009 while only *Cephalophus nigrifrons* was observed during in 2014. Both species were recorded by camera trap in 2014. Duiker dung encounter rate was significantly higher in 2014, for both groups and individuals. Calculation of density based on indirect signs also showed a population increased from 870 individuals in 2009 to an estimated 1,066 individuals in 2014. The density estimate of duiker was based on all species as identifying species of dung was not possible. Therefore it should be recognized that production rates of dung from different species of duiker may be variable and could affect the density estimates of this class. However, given that duikers are a preferred target species by poachers, their population increase (or recovery given the low numbers in 2009) could mean reduced hunting pressure in general (which does not seem to be the case from the results on human signs) or a shift in target species by the poachers (which may be more likely, given that poachers are frequently caught with smaller preys such as squirrels and forest Gambian rats).

Bushpig signs revealed an increase in encounter rates through time but, when analyzing the densities, this trend was reversed, with a decrease in density estimate from 0.966 individuals per km^2 in2009 to 0.692 individual per km^2 in 2014, corresponding to population estimates of 984 bushpig in 2009 and 706 bushpig in 2014. This difference, with a decrease in population and an increase in encounter rates through time was likely due to the left truncation that has been done as many records had zero as perpendicular distance and this reduced considerably the density. Considering data on 0cm perpendicular distance was biasing the results as density could increase up to 1,680 individual per km^2 with uncertain curve, consistently with the recorded increase in encounter rates.

For carnivores, overall the observations along the 2009-2014 transects indicated a decrease in encounter rates through time. However, the numbers of indirect signs observations were in general very low and lumped different species, making difficult any assessment on carnivoresô trends and population status. The only carnivore seen along the transect data collection in 2009 was the side-striped jackal (*Canis adustus*) while in 2014 the only carnivore seen was a genet (*Genetta tigrina*). Other carnivores that were recorded during the 2014 survey using camera traps include the Servaline genet (*Genetta servalina*), the African civet (*Civettictis civetta*), the African palm civet (*Nandinia binotata*), the blotched genet (*Genetta maculate*) and the side-striped jackal (*Canis adustus*). Carnivores are mostly solitary, cryptic and nocturnal and this will explain the low number of direct observations during daytime walking. Conversely, the 420 photographs of carnivores obtained in the 2014 camera trapping survey are a clear indication of the potentials of this method to survey nocturnal and more secretive species. No attempt was made to estimate density of specific carnivore species based on indirect sign, as identifying the species of dung for carnivores was not possible, and variability in dung production rates across a suite of carnivore species is likely to result in a spurious result for density.

Human signs

The results from the 2009-2014 survey should be inserted in the longer term scenario for Nyungwe. In the near past (70s, and 90s) some species that have used to occur in Nyungwe have gone extinct, such as the buffaloes and the African elephant. It has been estimated that some 20% of Nyungwe surface area has been lost since the colonial

era, due to logging and land conversion for agriculture (Fischer & Killmann, 2008), and 12% of habitat was destroyed due to human induced bushfires in the late 1990s. The 2009 and 2014 surveys recorded an increase in human signs (such as snares and tree cutting), a similar trend recorded from the Ranger Based Monitoring Program, where rangers record every sign of human activities and the area patrolled. Small mammals have been the main target in previous years but recently through the RBM it has been noticed that Gambian rat, squirrels, brush-tailed porcupines, duiker and bushpig have been among the major targets for poaching at Nyungwe National Park.

Few of the many correlations calculated between mammal sightings and edge of the park, roads and ranger posts produced statistically significant relationship. The results from 2009 and 2014 survey show that there was a significant negative correlation between blue monkeys and the edge of the park and the ranger posts. This negative correlation is almost certainly more related to crop raiding in the neighboring agriculture land that blue monkey may visit which may explain their preference being near the edge of the park considering also that all ranger post are located at the edge.

Duikers are mammals mostly targeted by poachers at Nyungwe National Park. These species tend to avoid the edge of the park and ranger post. The correlation of duikers to the edge of the park and ranger post in 2009 and 2014 although it is not significant (0.484 and 0.315 respectively), but the positive correlation shows that duikers avoid being at the edge of the park while the correlation to the road is significantly negative (-0.688) in 2014. This situation is a bit similar to the correlation of bush pig to the edge of the park and ranger post where is significantly positive (0.556 and 0.614 in 2014) but with no significant correlation to the road in both 2009 and 2014 (-0.278 and -0.175). This can be explained by the fact that Duiker and Bushpig have been among the targeted animal of poachers which causes these animal to avoid the edge of the park.

Threats to the biodiversity of Nyungwe are, in most cases, the results of human activities driven by dependency on park resources by community surrounding the park. The information on illegal activities is currently collected by ranger based monitoring where ranger patrol the park and report their findings in terms of observations and animal sighting. During the 2009 and 2014 survey, illegal activities observation encountered were collected along transect and their spearman rank correlation to the edge of the park, road and ranger post were calculated. In 2009, wood cutting has shown significant negative correlation to the edge, road and ranger post. This correlation mean that wood cutting happen more near the edge, road and ranger post for different purpose including fire wood, sawing, bean sticks, tree cutting for beehives etc. There was no significant correlation of wood cutting and edge, road and ranger post in 2014. Snares were more positively correlated to the edge of the park in 2014 while in 2009 they were significantly negative correlated to the edge of the park meaning that in 2014 snares were find more far from the edge while in 2009 snare were recorded more near the edge of the park. The reason was that in 2009 only 3 observations of snares were recorded at three different transect located near the edge of the park compare to 37 snares observations of snares in 2014. It should be noted there is a possibility that some number of significant correlations produced by the above analysis might be unauthentic considering number of observation of illegal activities recorded during the survey.

The lower detection rates in the bio-monitoring survey compared to the RBM methods is very likely a result of the fact that RBM follows illegal resource usersô path, actively trying to find people, snares mining sites etc., while on the bio-monitoring survey, observers have to limit their observations to the randomly set transects. Additionally, it seems also that people may avoid using line transects once they know that they are repeatedly used by park staff during the 5 months long park-wide survey.

While the survey results on densities, and encounter rates of animals in NNP and the various correlations have provided a mixed picture with some species increasing and others decreasing, the increase in illegal human activities in the park seems unequivocal. The intense and increased human pressure in the park is not surprising, considering the increasing human population living all around the parkôs border and depending on small farm-plots of ever decreasing productivity.

CONCLUSION AND RECOMMENDATIONS

The major challenge for conservation of Nyungwe today remains the high density of human population around it and the level of poverty among communities adjacent to Nyungwe. Communities living around the Nyungwe forest have always relied on the forest as a source of subsistence, providing goods such as wood, food, medicines, construction materials and tools. Poaching, land clearing for agriculture and mining is another form of park resource use leading species extinction and further park degradation. The shortage of agricultural land forces the population to encroach into the forest regardless of the infertility of soils. As Nyungwe surrounding communities will continue to rely on park resources, there is no doubt that further known and unknown impacts will be experienced.

Poaching remains to be of high concern within the Nyungwe National Park; this has already resulted in the extinction of the large mammals at Nyungwe (buffaloes and elephants) and results from our line transects and the RBM show high encounter rate of snaring which affects different species. Results from ranger-based monitoring show that, although the larger mammals such as bushpig and duiker are targeted by poachers, most snares found are targeting smaller species such as Gambian rats, squirrels and brush-tailed porcupines (*Atherurus Africana*). The primate populations in the NNP have largely been protected due to cultural tendencies to avoid eating primates. However, over the last few years there has been evidence of an increasing trend of primates being targeted by hunters. Terrestrial and semi-terrestrial species of primate may be more vulnerable to snares, such as the Albertine Rift endemic Lôhoestôs monkey, the near-endemic owl-faced monkey and the eastern chimpanzee. For Rwanda though, the Nyungwe National Park harbors the last remaining viable population of chimpanzees, grey-cheeked mangabey, red-tailed monkey, blue monkey, owl-faced monkey, Mona monkey, black and white Colobus.

Nyungwe National Park is a key area for conservation within the Albertine Rift and Rwanda. However, it has even greater conservation importance when taken as a landscape with Kibira National Park in Burundi. Landscape conservation has a higher chance of success with long-term survival of the species and habitats due to the larger

areas and is particularly important for species such as the chimpanzee. Transboundary conservation is a growing conservation priority and the development of transboundary collaborations between Rwanda and Burundi are making good headway. In Rwanda, where there is high human population pressure and conservation sites are isolated patches, remaining connectivity must be preserved as a priority (Plumptre et al, 2007) to ensure the long term survival of the species and habitats of Nyungwe Forest.

For success to Nyungwe ecosystem conservation, conservation effort shall consider the scenario of Albertine Rift endemic and threatened species, and the scenario of altitudinal forest levels. We shall note that as pressure on lower forest level will continue, Nyungwe will be at risk of losing important species, which are limited to this altitudinal fringe. This forest fringe is more important for habitat diversity including most rivers and swamps, and important larger trees remaining in Rwanda. Albertine endemic and global threatened species are for global importance for conservation and the effort of documenting these species shall continue. The swamp areas were not well sampled and we suggest a particular study to discover more about these important areas in Nyungwe ecosystem. Further survey is recommended for nocturnal primates as they were not covered in these surveys design.

Law Enforcement activities are critical, particularly where protected areas face problems of poaching or any other illegal activities, but need to be combined by efforts on community relations. Well-trained, well-equipped and motivated teams of rangers are fundamental to the success of law enforcement activities. But to be effective, the local enforcement effort needs to be backed by a broader environment of good and appropriate governance that ensures penalties are enforced. Lack of alternative livelihoods for a poor and growing local population have slowed the process, and efforts to curb illegal activities (such as mining, poaching, and fires) have not achieved the expected results. Local communities need to understand the importance of managing the national parkôs limited natural resources and learn ways to mitigate their impacts on the ecosystem, especially through the identification of sustainable income-generating alternatives.

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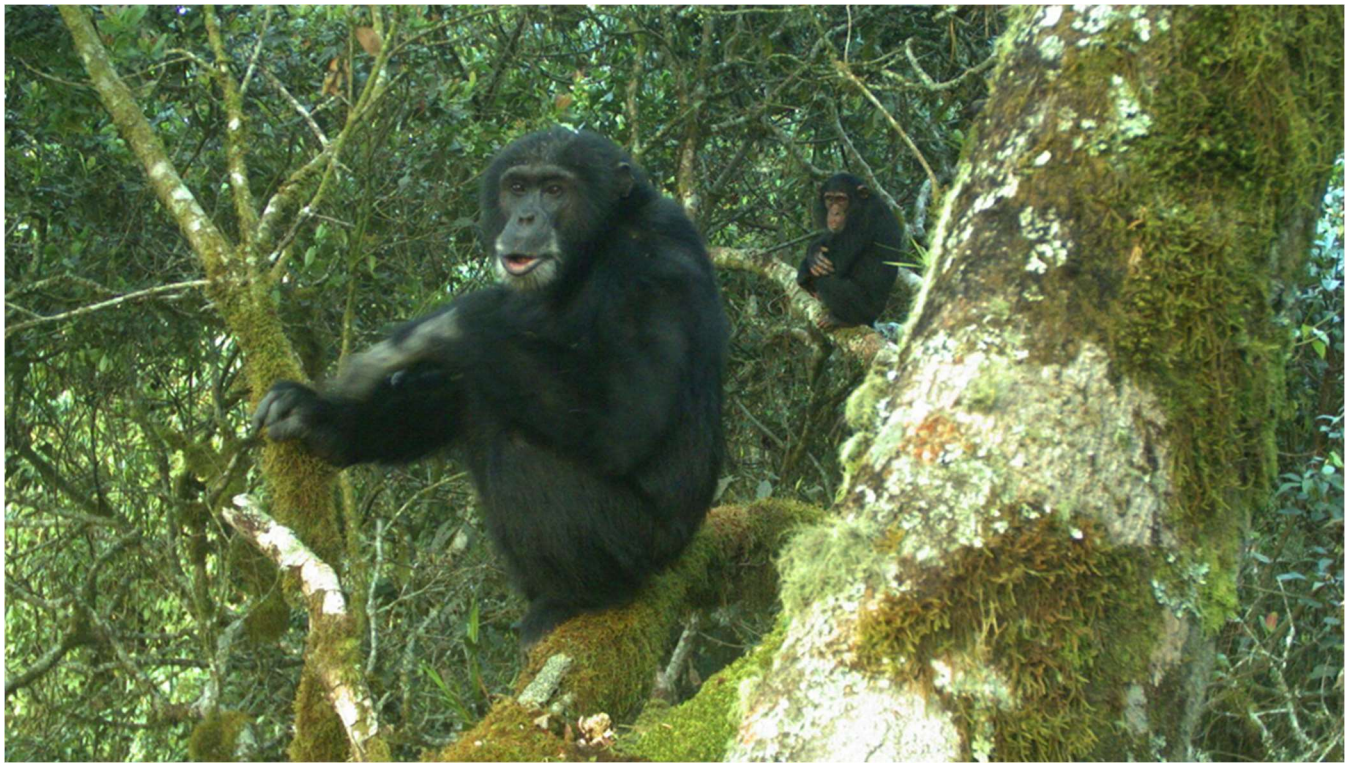
The status and trends of populations of Chimpanzee (*Pan troglodytes*) and other mammal species in Nyungwe National Park, Rwanda



Working Paper

By Felix Mulindahabi, Jennifer Moore, Protais Niyigaba, Gratien Gatorano, Placide Masengesho.

SUMMARY

The conservation of wild animals requires a detailed understanding of their population size, spatial distribution, and demographic trends. The status and trends of populations of most wild animal species including the Endangered eastern chimpanzee (*Pan troglodytes schweinfurthii*) is still poorly known, especially in developing countries such as Rwanda. Nevertheless, manpower and monetary resources continue to be devoted to properly document the conservation status of wild animal populations, especially species of global conservation concern such as *P. troglodytes schweinfurthii*. The survey of chimpanzee populations and other medium and large-sized mammals in Nyungwe National Park (NNP) was designed to provide this kind of information to inform park management.

We used line transect sampling and camera trapping to collect data over the same 41 line transects, systematically (with random start point) sampled across the national park in 2009, 2014, and 2021, and camera trapping at 82 and 64 locations for 2014 and 2021 respectively. The survey aimed to estimate density and occupancy of medium to large mammal species in NNP. Line transects data were analyzed using distance sampling models whereas camera trap data were analyzed using occupancy models. For species lacking enough data to estimate density, we calculated encounter rates instead, which are just the raw number of detections per kilometer walked.

Our results show that chimpanzee abundance has stayed fairly constant across the three surveys. The population of chimpanzee (*Pan troglodytes*) is estimated at an average of 398 individuals varying from 374 in 2009, 462 in 2014, and 358 individuals in 2021 in Nyungwe main forest. Duiker species show an increase in population from 1,847 to 3,959 individuals while blue monkey and bushpig show decline in population from 10,018 to 7,308 individuals, and from 355 to 193 individuals, respectively.

We estimated average species richness across the park at 13 species, with individual sites ranging from 5 to 28 species. For individual species, probability of occupancy varied from 0.113 for Boehm's bush squirrel to 0.845 for L'hoest's monkeys with detection probability varying from 0.215 to 0.694. These results showed that black-fronted duiker increased in occupancy, whereas brush-tailed porcupine and bushpig declined in occupancy from 2014 to 2021. However, we were unable to run occupancy model for some species, which had fewer detections.

We recommend further studies to examine the possible reasons for species that show a decline in population density or occupancy especially blue monkey and bushpig. Also, we recommend deploying additional camera traps for longer periods of time to increase the

probability of detecting rare species. The results from this study are important to update the general management plan for NNP as well as designing specific research topics in the future.

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INTRODUCTION

The conservation of wild animals requires a detailed understanding of their population size, spatial distribution, and their demographic trends (Edwards et al., 2012; White & Edwards Eds, 2000). The survey of chimpanzee population and other medium and large-sized mammals in Nyungwe National Park (NNP) was designed to provide this kind of information to inform park management strategic decision making. Although mammal population surveys in NNP started in 1990 (Dowsett, 1990; Plumptre et al., 2002), in reality, the populations status and trends of most animal species including the Endangered eastern chimpanzee (*Pan troglodytes schweinfurthii*) is still poorly known. This is because most of the medium to large animal species in NNP occur in low densities, and often in remote places with limited access (lack or poor road, rugged and mountainous terrain, and dense understory vegetation, etc.), and the cryptic nature of some of these species make the implementation of wild animal population survey programs extremely difficult. Nevertheless, manpower and monetary resources continue to be devoted to properly document the conservation status of wild animal populations including *Pan troglodytes schweinfurthii* (Plumptre, 2010; Kormos & Boesch, 2003). Data on animal populations, especially species of global conservation concern such as *P. troglodytes schweinfurthii*, are essential for IUCN Red List of Threatened species assessments to evaluate their conservation status, as well as for protected managers to make science-based decisions.

Mammal lists for Nyungwe shows 86 species of which 14 species are endemic in the Albertine Rift, and 16 species are classified as either Critically Endangered, Endangered, Vulnerable or Near Threatened (Plumptre et al., 2007). At least 40 (46.5%) species (excluding bats) of mammal species in NNP are categorized as small mammals and include shrews and rodents. The rest are labeled as “medium to large mammal species”, and they include primates, antelopes, bushpig, carnivores, and some rodents.

NNP is world renowned for its primate populations with 13 different species namely Blue Monkey (*Cercopithecus mitis doggetti*), Eastern Chimpanzee (*Pan troglodytes schweinfurthii*), Golden Monkey (*Cercopithecus mitis kandti*), Grey-cheeked Mangabey (*Lophocebus albigena*), L’hoest Monkey or Mountain Monkey (*Allochrocebus lhoesti*), Mona Monkey (*Cercopithecus denti*), Olive Baboon (*Papio anubis*), Owl-faced Guenon (*Cercopithecus hamlyni*), Red-tailed Monkey (*Cercopithecus ascanius*), Rwenzori Black-and-White Colobus (*Colobus angolensis ruwenzorii*), Vervet Monkey (*Chlorocebus pygerythrus*), Thomas’s Galago (*Galagoides thomasi*), Spectacled Lesser Galago (*Galago matschiei*), and Eastern Potto (*Perodicticus ibeanus*). However, there are no recent records of Golden Monkey (*Cercopithecus mitis kandti*) in NNP (Chao et al., 2010). Concerning antelopes and pigs, 6 species were reported in NNP, and comprise of Black-fronted Duiker (*Cephalophus*

nigrifrons), Lestrade's Duiker (*Cephalophus weynsi lestradei*), Yellow-backed Duiker (*Cephalophus silvicultor*), Bushbuck (*Tragelaphus scriptus*), Bushpig (*Potamochoerus larvatus*), and Giant Forest Hog (*Hylochoerus meinertzhageni*). There was no recent record of *H. meinertzhageni* in NNP for the last 30 years.

Nyungwe provides habitat for at least 17 carnivore species including African Civet (*Civettictis civetta*), Central African Oyan (*Poiana richardsonii*), African Palm Civet (*Nandinia binotata*), African Striped Weasel (*Poecilogale albinucha*) , African Wild Cat (*Felis silvestris*), Congo Clawless Otter (Aonyx congicus), Egyptian Mongoose (*Herpestes ichneumon*), Giant Genet (*Genetta victoriae*), Large-spotted Genet (Genetta maculata), Marsh Mongoose (Atilax paludinosus), Side-striped Jackal (*Canis adustus*), Serval (*Leptailurus serval*), Servaline Genet (*Genetta servalina*), Slender Mongoose (*Herpestes sanguineus*) , Honey Badger (*Mellivora capensis*), and finally African Golden Cat (*Caracal aurata*) and Leopard (*Panthera pardus*), which were not recorded in last 30 years. In the category of medium to large mammal, we also include 7 species of squirrels, African Brush-tailed Porcupine (*Atherurus africanus*), Gambian Rat (*Cricetomys gambianus*), and Southern Tree Hyrax (*Dendrohyrax arboreus*).

Other taxa in Nyungwe include 280 birds, 33 amphibians, 43 reptiles and 1105 plant species (Plumptre et al.., 2007; Chao et al., 2010; Easton et al., 2011; Moore et al., 2020; Moore et al., 2018; Barakabuye et al., 2007).

Nyungwe is also known for its richness in species endemism in Albertine Rift including 280 (25.3%) plant species, 14 (42.42%) amphibians, 8(18.6%) reptiles, 26 (9.28%) birds, and 22 species classified as Critically Endangered (CR), Endangered (EN), or Vulnerable (VU) on the IUCN Red List of Threatened species (Plumptreet al., 2007; Fischer & Killmann, 2008).

Mammal species richness and its populations as well as their habitat in NNP were shaped by human activities primarily deforestation and habitat disturbances over several years. Communities living around NNP have always relied on the forest as a source of subsistence, providing goods such as wood, food, medicines, construction materials and tools (Masozera & Alavalapati, 2004). Wildfires, road building, mining, land conversion to agriculture, and illegal harvesting of trees for timber, fuel and fodder have caused major habitat changes in this national park (Chao et al., 2010). Because of these activities, many of the large-bodied mammals (mega fauna) have been seriously depleted or completely eliminated from NNP. Bushbuck, Yellow-backed duikers and bush pig all survive but in low numbers. There have been no recent confirmed sightings of leopard (*Panthera pardus*), giant forest hog, golden cat (*Felis aurata*) or spotted hyaena (*Crocuta crocuta*), although these species once occurred in Nyungwe (Storz, 1982). Nyungwe has lost its forest buffalo and elephant populations since 1970s due to hunting (Chao et al., 2010). Furthermore, since 1997-98, approximately an area > 10% of the park was destroyed by wildfires is

causing a significant impact on biodiversity. Burned areas were found to be poor habitat for wildlife, with few signs of duikers, carnivores and bushpigs, and no primates. Hunting in NNP is a major threat to mammal populations, and it is predominantly carried out for subsistence needs with some evidence that meat of wild animals is sold in local markets (Chao et al., 2010). Animal species targeted for hunting range from larger mammals such as bushpigs and antelopes to small-sized species such as the pouched Gambian rats, squirrels and porcupines. According to Chao et al., 2010, Moore et al., 2017, more than 2,451 snares were detected in NNP each year considering ranger-based monitoring (RBM) data from 2003 to 2009, and more than 1,900 poaching-related threats each year considering 2006-2015 RBM data.

GOAL AND OBJECTIVES

The goal of the animal population surveys in NNP is to support the Rwandan government's biodiversity conservation goals, specifically, to ensure long-term conservation of the eastern chimpanzee (*Pan troglodytes schweinfurthii*) and other wildlife in their natural habitat. The objective of 2021survey and past surveys (2009 &2014) was to assess the status and trends of eastern chimpanzee (*Pan troglodytes schweinfurthii*), and other mammal species populations to update the Nyungwe general management plan and research priorities. Specifically, the objective was to provide updated and scientific information on the status and trends (size of population, density, spatial distribution, relative abundance, species richness) of chimpanzee population and other mammal species in Nyungwe National Park in the last 12 years (2009 – 2021).

METHODOLOGY

In 2009, WCS designed a park-wide survey using distance sampling software "Distance 6.0 Release 2" (Thomas et al., 2009) and established forty-one, 3km line transects systematically in a north - south orientation, with a random start point (Figure 1) to survey medium to large mammal and bird species. These transects were used to conduct park-wide surveys in 2009, 2014, and 2021 by collecting data from across NNP using the same survey design and methodology and as much as possible the same team members. For all years, data collection took place throughout the months from June to September, typically the months of the dry season with the start of the rainy season in September. The surveys involved 6 – 7 teams that worked simultaneously across the entire park and were composed of a principal observer responsible for sightings and a second observer who observed signs on the ground, including human signs.

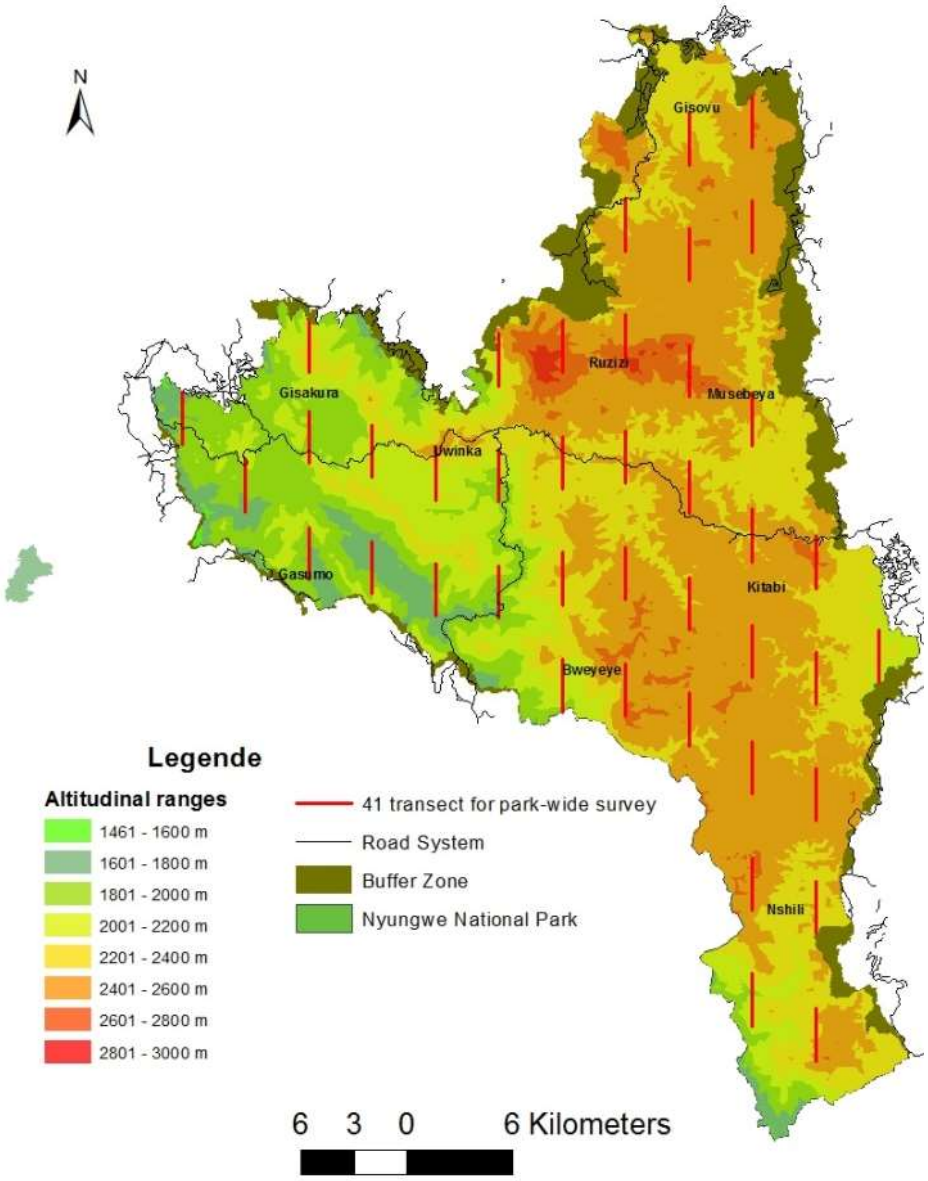


Figure 1 Park-wide survey transect design in Nyungwe National Park

Training

Prior to the survey, field teams were formed in May and received a 5-day training in June 2021 on the methodology to survey chimpanzees, and other mammals including line transect sampling, and camera trapping. Field teams were also trained on:

- the use of field equipment including use of GPS to record geographic information,
- the use of camera traps including setting and selection of their location/placement,
- the use of hip chain and topofil/hip chain thread to measure distance traveled,

- the use of range finders to measure perpendicular distances,
- animal identification using morphological characteristics,
- filling out data sheets.

Line Transect Sampling

Line transect sampling (Buckland et al., 2001) was used to record observations of medium and large ground dwelling and arboreal mammals, notably primates (Plumptre & Reynolds, 1996). The survey started with transect-cutting phase -only data on illegal activities (human signs), and animal signs were collected (as the cutting noise would bias animal observations). Signs were either marked (for nests) or removed (for dung) to avoid recounts during subsequent visits. Each transect was revisited three times following transect cutting (with 19 days between visits); researchers recorded all indirect signs and direct observations seen from the transect. Perpendicular distance from transect to individual animal or the center of the group of animals was measured using a tape meter or range finder and the total number of individuals was recorded. Only individual animals, chimpanzee nests, dung, and human sign detected from each transect were recorded in these surveys. GPS coordinates were collected for each sighting and at every 250 m along transects.

During the survey, the following information was recorded:

(1) Marking distance interval: Distance was marked from the beginning 0m and every 250m to the end of transect. Habitat was recorded at each 250 meters using the following 11 habitat types:
   - Tall Closed Forest (TCF): 50% or more of the forest canopy is closed, trees >15m tall.
   - Short Closed Forest (SCF): 50% or more of the forest canopy is closed, trees <15m tall.
   - Tall Open Forest (TOF): less than 50% of the forest canopy is closed, trees >15m tall.
   - Short Open Forest (SOF): less than 50% of the forest canopy is closed, trees <15m tall.
   - Clearing (CL): open areas of at least 20 m radius, without trees, that are dominated by *Sericostachys*, *Mimulopsis*, and other herbaceous or secondary vegetation.
   - Human Clearing (HCL): human clearing through agriculture (crop or marijuana)
   - Fern/burnt forest gaps of at least 20m radius, without trees, and dominated by ferns.
   - Wetland: areas dominated by waterlogged soil.
   - Bamboo: areas dominated by *Sinarundinaria alpina*.

- Mixed Bamboo Forest: areas of bamboo intermixed with other forest species.
- Savanna: areas of at least 20m radius dominated by grassland.
- Shrubs: areas of shrubs less than 12m high, without trees.

(2) Recording and marking chimpanzee nests: all nests observed from transect were recorded and marked (to avoid recount), and perpendicular distance measured in meters (m) for individual nest from transect to the nest (when range finders were intercepted by thick vegetation or failed to work, we used 50 meters tape measures instead). All nest age categories were recorded during transect cutting whereas the following visits, the team recorded only new nests (nests made after previous visit). Nests were classified into four age categories:
   - Fresh: all leaves in the nest are green and generally feces or urine odors were underneath the nest.
   - Dry: leaves mostly dry with different color but still intact
   - Old: nest with holes showing few or no leaves, but still identifiable by bent twigs
   - Very old: leaves dead and often holes in the nest cup

(3) Indirect observations of animals and human signs: all animal signs (dung) for bushpig, carnivores, and duiker observed were recorded, and measured perpendicular distance in centimeters (cm). Because it was not easy to distinguish specific species from dung, observers recorded dung by group of species: duikers, carnivores, and bushpig. Observers also recorded human signs including snares, mining, trails of resource users, fireplaces, camp sites, beehives and when encountered, people (illegal resource users). The perpendicular distance from transect to the sign was recorded and measured in centimeters (cm), and the recorded sign was destroyed/erased to avoid recount the next visit.

(4) Direct observation of animals: all animals observed were recorded, and we measured the perpendicular distance in meters (m) from the transect to the individual animal or the center of the animal group.

Camera Trapping Sampling

Camera trapping is an increasingly popular survey tool widely used to study wildlife, and it is a fundamental method for species inventory and occupancy (Ahumada et al., 2011, 2013; Karanth, 2015; Moore et al., 2020; Mugerwa et al., 2012; Rowcliffe et al., 2008; Silver et al., 2004). This tool is generally regarded as non-invasive, and it can gather information on a range of species simultaneously (including cryptic and rare species) and continuously over large survey areas and for several months at a time. WCS started using camera traps in 2008; however, camera traps were opportunistically deployed in the park where staff was working and where signs of animals were seen, and they were not deployed systematically in the 2009 survey.

For the 2014 and 2021 biodiversity surveys, camera traps were deployed throughout the park following transect design to capture shy and nocturnal species with emphasis on carnivores, ungulates and terrestrial birds that are not frequently observed during transect walking (duiker, bush pigs, carnivores, etc.). In 2014, we planned to deploy camera traps at the beginning and the end point of each of 41 transect but we had only 78 cameras well-functioning. In total 78 camera traps were installed in 78 locations on ground; unfortunately, 11 cameras failed in the field due to poor setup (2 cameras), incorrect camera trap settings (1 camera) and unknown failures (8 cameras). In the end, we used images from 67 points. In 2021, two cameras (one on the ground and one in the canopy) were installed at the beginning and end of each of 32 transects (64 locations). We included camera traps in the tree canopy (arboreal camera) to maximize detection of all species (Moore et al., 2020). Nine transects (18 camera trap points) were not sampled due to limited accessibility and due to issues with the camera traps that did not work during testing prior to the first deployment, no camera traps were deployed at transect 8 and only one camera trap was deployed at transects 18 and 41. In these survey, three types of digital camera traps were used: Reconyx hyperfire (HC500 and PC800 models), Reconyx rapidfire (RM45 model) and Bushnell (119437 model). To maximize the quality of images, their settings were harmonized, adapted from the Tropical Ecology Assessment and Monitoring (TEAM) Network protocol on Terrestrial Vertebrate (Camera Trap) Monitoring published by Conservation International in 2011. Each camera trap spent a minimum of 30 to 40 days at each location and the memory card and batteries were changed before relocation.

DATA ANALYSIS

Line Transect Surveys

Line transect data coupled with distance sampling models (Buckland et al. 2001) were used to estimate density and abundance of key species within the park using data across the 3 park-wide surveys (2009, 2014, and 2021). Each year was modelled separately considering the number of transects walked in each survey as well as the number of times each transect was walked. For each species, detection functions were fit to the data using 3 different likelihood functions: half normal, hazard rate, and uniform. In addition, we fit models including 4 different potential covariates: habitat, elevation zone, distance to nearest access point, and distance to nearest tourist trail. We compared these 12 models for each species for each year using AIC, and then estimated density and abundance based on the top model (i.e., model with the lowest AIC score). Models that did not converge were removed before comparing models.

For chimpanzees, data were collected on chimpanzee nests instead of direct sightings. Therefore, estimates of chimpanzee nest density was converted to chimpanzee density by dividing by the product of nest production rate and mean time between surveys (1.09 * 19). Nest production rate was taken from studies of the same species in Uganda (Plumptre and Cox, 2006). Chimpanzee density was converted to abundance/population by multiplying chimpanzee density by park size (1,015 km^2) and correction factor of 1.20 for chimpanzees less than 4 years old (chimpanzees that do not build nests (Plumptre and Cox, 2006).

For duikers and bushpig, data were collected on dung instead of direct sightings, so dung density was converted to animal density. Dung density was divided by dung production rate (4.4 for duikers and 7 for bushpig) and mean time between surveys (19).

For other species, density was converted to abundance by multiplying by park size. Duiker density and abundance was combined for all duiker species as dung cannot be easily distinguished between species in the field. Density and abundance of blue monkeys were estimated using direct sightings from the line transect surveys.

Camera Trap Surveys

Single-season occupancy (MacKenzie et al. 2003, 2005) coupled with camera trap data were used to estimate species richness and individual species occupancy for 2021. In 2021, each site had two cameras – one at ground-level and one in the canopy. Detection histories were combined across these two cameras to create a single detection history for

each site and used to estimate species richness and individual species occupancy across the park. For all models, 10-day sampling occasions were used.

Since only ground camera traps were used in 2014, occupancy for ground-dwelling species only (species that cannot be detected on canopy camera traps) was compared between 2014 and 2021 using multi-season occupancy models (MacKenzie et al. 2005). Multi-season occupancy models allowed us to estimate probability of colonization and extinction between surveys in addition to the probability of occupancy for each survey year.

RESULTS

Line Transect Surveys

During the 2009 – 2014 - 2021 line transect surveys, a maximum of 28 species of medium and large mammals were recorded per transect, with 13 species per transect recorded in 2009, 16 species in 2014 and 28 in 2021.

Ten species of primates were recorded which include *Cercopithecus Ascanius*, *Cercopithecus hamlyni*, *Cercopithecus lhoesti*, *Cercopithecus mitis*, *Colobus angolensis*, *Galago matschiei*, *Galagoides thomasi*, *Lophocebus albigena*, *Pan troglodytes*, *and Perodicticus potto*. Golden monkey, Olive Baboon (*Papio anubis*) and Vervet Monkey (*Chlorocebus pygerythrus*) were not detected in any of the three surveys.

Four species of antelopes and 2 species of pigs are believed to live in Nyungwe National Park. Black-fronted Duiker (*Cephalophus nigrifrons*), Yellow-backed Duiker (*Cephalophus silvicultor*), Bushbuck (*Tragelaphus scriptus*), Lestrade's Duiker (*Cephalophus weynsi lestradei*), and Bushpig (*Potamochoerus larvatus*) were detected in these 3 surveys and are widely distributed primarily in the eastern and northern part of the park. Giant Forest Hog (*Hylochoerus meinertzhageni*) was not recorded.

Ten species of carnivores were recorded: *Canis adustus*, *Civettictis civetta*, *Genetta maculate*, *Genetta servalina*, *Herpestes ichneumon*, *Herpestes sanguineus*, *Leptailurus serval*, *Mellivora capensis*, *Nandinia binotata*, *and Poiana richardsonii*.

Eight species of rodent were recorded: *Anomalurus derbianus*, *Atherurus africanus*, *Cricetomys gambianus*, *Funisciurus carruthersi*, *Funisciurus pyrropus*, *Heliosciurus ruwenzorii*, *Paraxerus alexandri and Paraxerus boehmi*.

Encounter rates for all mammal's species directly or indirectly detected on line-transect surveys across 2009, 2014, and 2021 were calculated. Encounter rates are simply the number of detections divided by the total distance walked, so these measures do not account for detection. Therefore, an increase or decrease in encounter rate for a species across years does not necessarily represent an increase or decrease in abundance of that species. The total distance walked for direct and indirect observations was 492 km in 2009, 796 km for indirect observations and 663 km for direct observations in 2014, and 479 km for indirect observations and 359 km for direct observation in 2021. Encounter rates for direct sightings are included in Table 1 and encounter rates for indirect sightings are included in Table 2. Indirect sightings include nests and dung of all ages in Table 2, even though only fresh and dry nests and dung were used for the density/abundance analysis.

Table 1: Encounter rates for direct sightings of all species for 2009, 2014, and 2021.

Data include the number of individuals sights, the number of groups sighted, as well as the individual and group encounter rates.

Species	Year	Number of Individuals	Number of Groups	Individual Encounter Rate (Ind/km)	Group Encounter Rate (Group/km)
Angolan Colobus	2009	1420	14	2.886	0.028
	2014	524	7	0.790	0.011
	2021	210	5	0.585	0.014
Blue Monkey	2009	409	61	0.831	0.124
	2014	222	53	0.335	0.080
	2021	163	34	0.454	0.095
Chimpanzee	2009	50	11	0.102	0.022
	2014	29	9	0.044	0.014
	2021	9	3	0.025	0.008
Grey-cheeked Mangabey	2009	262	16	0.533	0.033
	2014	65	14	0.098	0.021
	2021	4	1	0.011	0.003
L'hoest Monkey	2009	71	16	0.144	0.033
	2014	130	35	0.196	0.053
	2021	79	23	0.220	0.064
Mona Monkey	2009	86	4	0.175	0.008
	2014	19	2	0.029	0.003
	2021	4	1	0.011	0.003
Owl-faced Monkey	2009	3	1	0.006	0.002
	2014	0	0	0.000	0.000
	2021	3	3	0.008	0.008
Red-tailed Monkey	2009	0	0	0.000	0.000
	2014	12	1	0.018	0.002
	2021	0	0	0.000	0.000
African Giant Squirrel	2009	-	-	-	-
	2014	3	3	0.005	0.005
	2021	0	0	0.000	0.000
Alexander's Squirrel	2009	-	-	-	-
	2014	25	19	0.038	0.029
	2021	9	7	0.025	0.019
Boehm's Squirrel	2009	-	-	-	-
	2014	91	72	0.137	0.109
	2021	21	18	0.058	0.050
Carruther's Squirrel	2009	-	-	-	-
	2014	203	146	0.306	0.220
	2021	81	68	0.226	0.189
Fire-footed Rope Squirrel	2009	-	-	-	-
	2014	23	20	0.035	0.030
	2021	0	0	0.000	0.000

Species	Year	Number of Individuals	Number of Groups	Individual Encounter Rate (Ind/km)	Group Encounter Rate (Group/km)
Ruwenzori Sun Squirrel	2009	-	-	-	-
	2014	55	46	0.083	0.069
	2021	5	5	0.014	0.014
Black-fronted Duiker	2009	9	5	0.018	0.010
	2014	20	19	0.030	0.029
	2021	41	39	0.114	0.109
Bushpig	2009	5	1	0.010	0.002
	2014	1	1	0.002	0.002
	2021	26	19	0.072	0.053
Hyrax	2009	0	0	0.000	0.000
	2014	0	0	0.000	0.000
	2021	1	1	0.003	0.003
Jackal	2009	1	1	0.002	0.002
	2014	0	0	0.000	0.000
	2021	0	0	0.000	0.000
Large-Spotted Genet	2009	0	0	0.000	0.000
	2014	1	1	0.002	0.002
	2021	0	0	0.000	0.000
Servaline Genet	2009	0	0	0.000	0.000
	2014	0	0	0.000	0.000
	2021	1	1	0.003	0.003
Yellow-backed Duiker	2009	2	1	0.004	0.002
	2014	0	0	0.000	0.000
	2021	1	1	0.003	0.003

Table 2: Encounter rates for indirect sightings of chimpanzee nests and animal dung including observations of all ages.

Data include number of individual nests/dung piles sighted, number of groups of nests/dung sighted, as well as individual and group encounter rates.

Species	Year	Number of Individual Nest/Dung Piles	Number of Groups of Nests/Dung Piles	Individual Encounter Rate (Ind/km)	Group Encounter Rate (group/km)
Chimpanzee Nest	2009	362	351	0.736	0.713
	2014	564	536	0.709	0.673
	2021	297	297	0.620	0.620
Bushpig Dung	2009	86	57	0.175	0.116
	2014	169	148	0.212	0.186
	2021	165	136	0.344	0.284
Carnivore Dung	2009	63	54	0.128	0.110
	2014	10	10	0.013	0.013
	2021	14	14	0.029	0.029
Chimpanzee Dung	2009	0	0	0.000	0.000
	2014	71	71	0.089	0.089
	2021	0	0	0.000	0.000
Duiker Dung	2009	80	72	0.163	0.146
	2014	204	181	0.256	0.227
	2021	1638	1316	3.420	2.747

We calculated density and abundance based on chimpanzee nests, duiker dung, bushpig dung, and direct observations of blue monkey. The results are shown in Table 3 below:

Table 3: Distance sampling model results. Estimated detection probability, nest/dung density, animal density, and animal abundance from the top-ranked distance sampling model for each species for each year. The likelihood function and covariate included on the model are also provided as well as the number of observations for each year.

Species	Year	Observations	Likelihood Function	Covariate	Estimated Detection Probability	Nest/Dung Density (per km)	Animal Density (per km)	Animal Abundance (park-wide)
Chimpanzee	2009	179	Half-normal	Habitat	0.29 (SE = 0.02)	6.36 (3.85, 10.51)	0.31 (0.19, 0.51)	374 (226, 618)
	2014	309	Half-normal	Access	0.35 (SE = 0.01)	7.85 (4.40, 14.02)	0.38 (0.21, 0.68)	462 (259, 825)
	2021	101	Hazard rate	Access	0.29 (SE = 0.04)	6.08 (3.37, 10.94)	0.29 (0.16, 0.53)	358 (198, 643)
Duiker	2009	60	Hazard rate	Habitat	0.04 (SE = 0.02)	151.89 (49.44, 466.64)	1.82 (0.59, 5.58)	1847 (599, 5664)
	2014	125	Hazard rate	Trail	0.03 (SE = 0.01)	503.23 (244.55, 1035.50)	6.02 (2.93, 12.39)	6110 (2974, 12576)
	2021	776	Half-normal	Elevation	0.41 (SE = 0.01)	326.84 (186.07, 570.61)	3.90 (2.23, 6.83)	3959 (2263, 6932)
Bushpig	2009	33	Half-normal	Elevation	0.18 (SE = 0.02)	46.60 (21.06, 103.09)	0.35 (0.16, 0.78)	355 (162, 792)
	2014	104	Half-normal	Habitat	0.23 (SE = 0.01)	46.30 (27.41, 78.21)	0.35 (0.21, 0.59)	355 (213, 599)
	2021	59	Half-normal	Habitat	0.40 (SE = 0.07)	25.65 (13.12, 50.14)	0.19 (0.10, 0.38)	193 (102, 386)
Blue Monkey	2009	61	Hazard rate	Access	0.40 (SE = 0.08)	-	9.87 (5.66, 17.22)	10018 (5745, 17478)
	2014	53	Hazard rate	Trail	0.54 (SE = 0.16)	-	4.36 (1.91, 9.98)	4425 (1939, 10130)
	2021	34	Half-normal	Trail	0.37 (SE = 0.05)	-	7.20 (3.82, 13.59)	7308 (3877, 13794)

Our results show that chimpanzee abundance has stayed fairly constant across the 2009, 2014 and 2021 surveys. The population of chimpanzees (*Pan troglodytes)* is estimated at an average of 398 individuals varying from 374 in 2009, 462 in 2014, and 358 individuals in 2021 in Nyungwe main forest. Although the point estimates have changed slightly between surveys, the 95% confidence intervals around these estimates overlap across all three years, which shows that there is no significant difference between these estimates.

For duikers, it appears to be a slight increase across the surveys; however, there is uncertainty in the estimates based on the lower number of detections of dung in the first two surveys compared to the 2021 survey. Based on the models, the probability of detection increased greatly between the first two surveys compared to the 2021 survey, and thus the abundance estimate is more precise for 2021,with population size estimated at 3,781 (2156 - 6621) individuals with a density of 3.9 (2.23 – 6.83) individuals per kilometer squared.

Abundance of bushpig has slightly declined across the three surveys, although there is significant overlap between the 95% confidence intervals for the three years. There is a lack of precision in these estimates as there are few bushpig dung detections in some surveys.

The average population estimate for the blue monkey (*Cercopithecus mitis doggetti*) is 7,250 individuals. In the 3 surveys, the population showed a decline from 10,018 individuals in 2009 to 4,425 in 2014, then a slight increase to 7,308 in 2021. Again, there is a lack of precision in these estimates because the size of the sample was small, however there is an overlap in the 95% confidence intervals around these estimates across the three surveys.

Camera Trap Surveys

We estimated average species richness at 13 species across the park, with individual sites ranging from 5 to 28 species (Figure 2). For individual species, probability of occupancy varied from 0.113 for Boehm's bush squirrel to 0.845 for L'hoest monkeys with detection probability varying from 0.215 to 0.694 (Table 4).

We were unable to run occupancy for a few species, which were detected at 3 or less sites total during the study period. This included: owl-faced monkey (1 site), Angolan colobus monkey (2 sites), large-spotted genet (2 sites), woodland dormouse (3 sites), Ruwenzori sun squirrel (3 sites), grey-cheeked mangabey (1 site), African palm civet (3 sites), Potto (1 site), and the Central African oyan (1 site). Distributions of all species based on raw data

(showing sites where the species was detected by cameras in 2021) are shown in Figure 3.

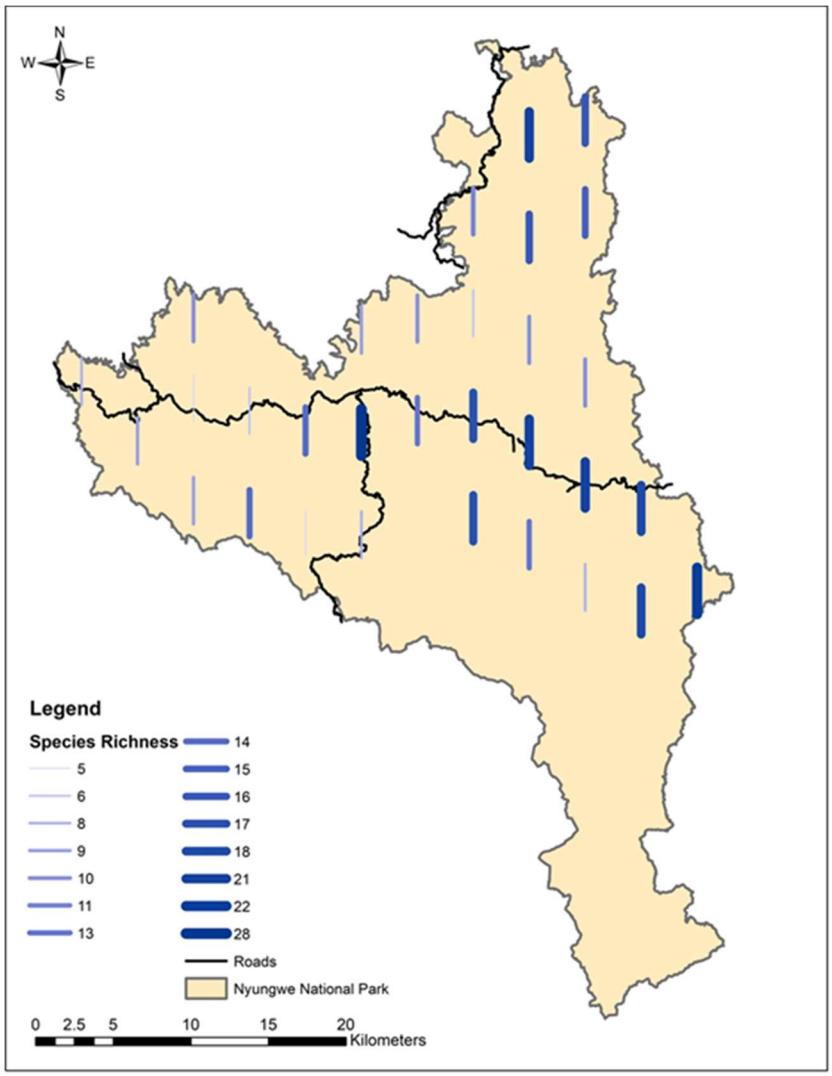
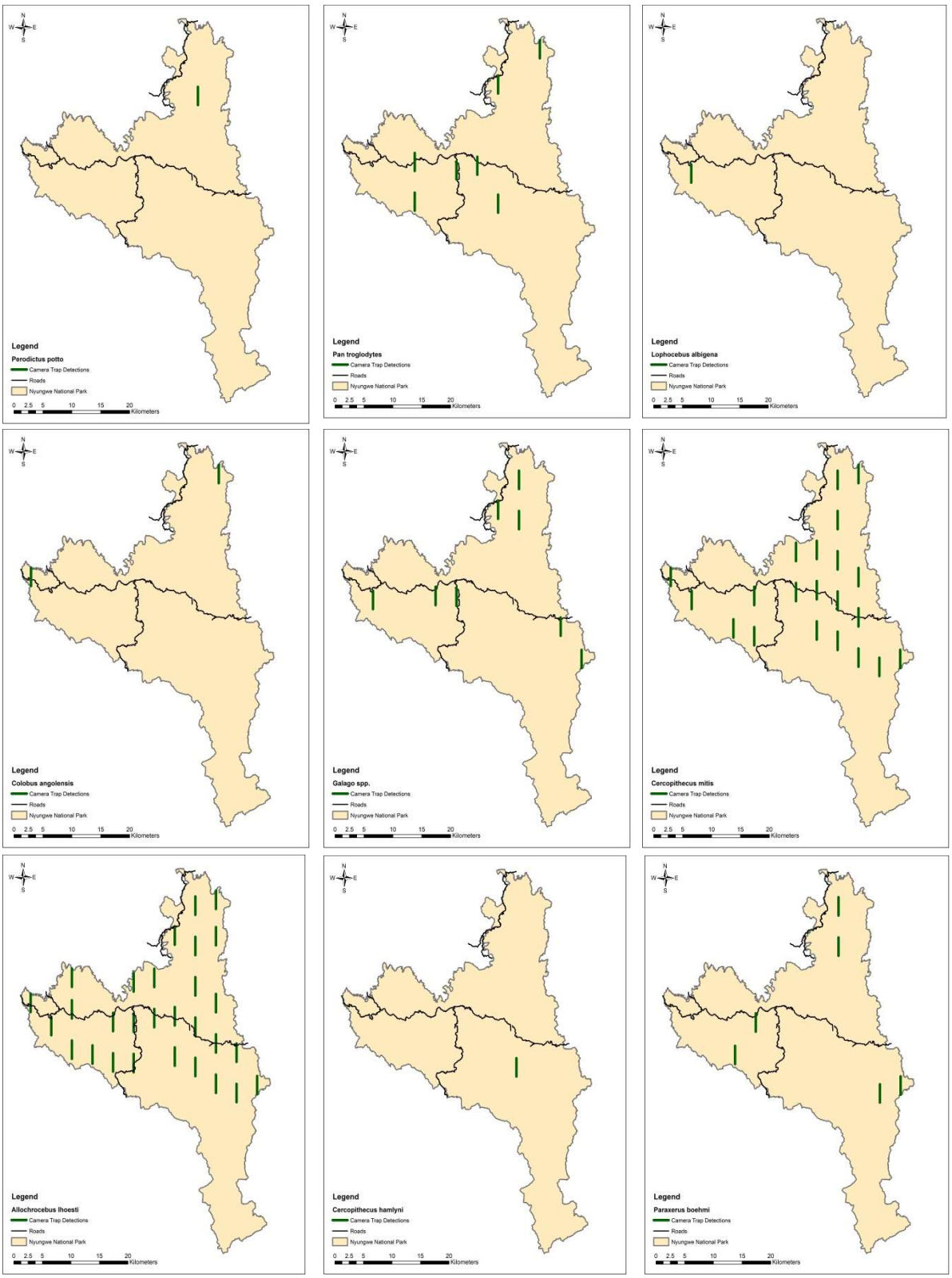
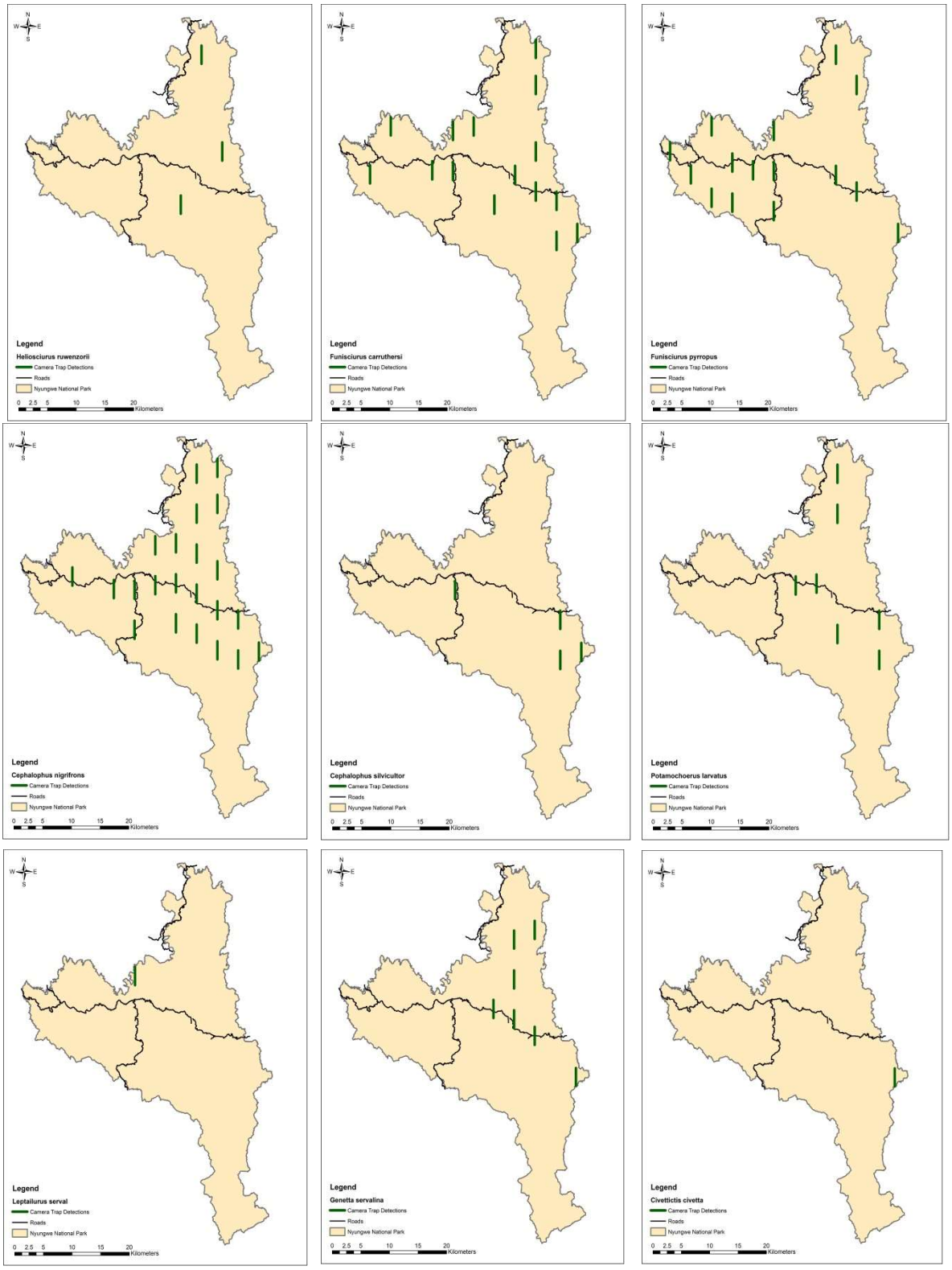


Figure 2: Estimated species richness by transect across the park using camera trap data from 2021.


Legend
Perodictus potto
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers
Legend
Pan troglodytes
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers
Legend
Lophocebus albigena
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers
Legend
Colobus angolensis
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers
Legend
Galago spp.
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers
Legend
Cercopithecus mitis
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers
Legend
Allochrocebus lhoesti
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers
Legend
Cercopithecus hamlyni
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers
Legend
Paraxerus boehmi
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers


Legend
Heliosciurus ruwenzorii
Funisciurus carruthersi
Funisciurus pyrropus
Cephalophus nigrifrons
Cephalophus silvicultor
Potamochoerus larvatus
Leptailurus serval
Genetta servalina
Civettictis civetta
Camera Trap Detections
Roads
Nyungwe National Park
0 2.5 5 10 15 20
Kilometers

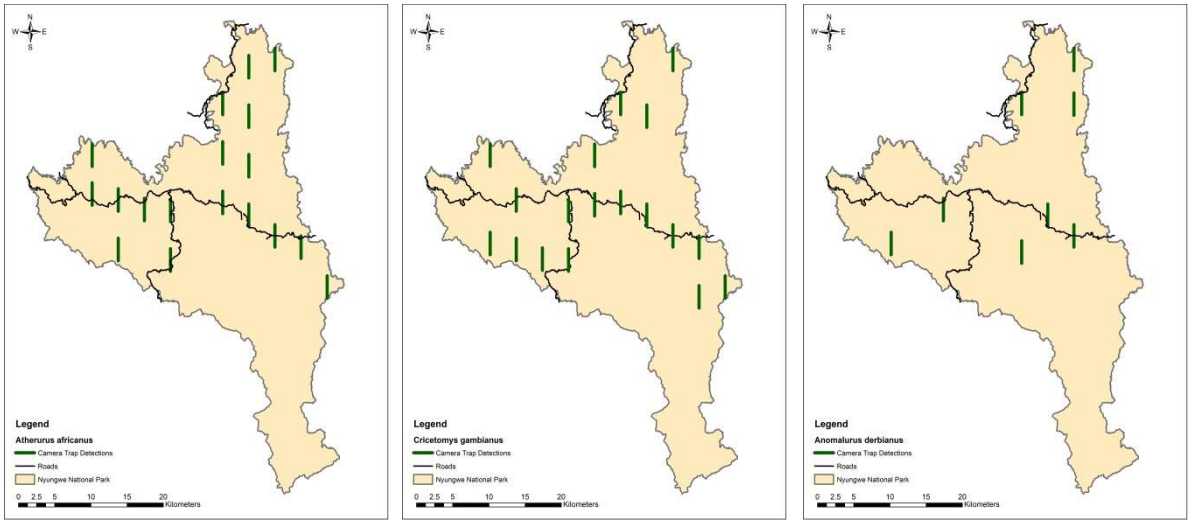


Figure 3: Distribution of all 28 species that were detected during camera traps surveys in 2021. Transect lines shown on each map are transects where each species was detected by camera traps, transect lines now shown were ones where the species was not detected.

For species that are ground-dwelling, we compared occupancy between 2014 and 2021, and calculated probability of colonization and extinction (Table 5). The results show that black-fronted duiker increased in occupancy from 2014 to 2021, with a higher probability of colonization than probability of extinction. However, brush-tailed porcupine and bushpig declined in occupancy from 2014 to 2021 and had higher probability of extinction than probability of colonization. Because there were few detections of carnivores, we combined all ground-dwelling carnivore species into a single detection history and fit the data to a multi-season model. We found that occupancy was the same between 2014 and 2021; however, probability of extinction was essentially 100%. This result was because the same number of sites were occupied in each year, but there was no overlap in these occupied sites. Therefore, all sites that were occupied in 2014 were no longer occupied in 2021.

We were unable to run occupancy models for a few species, which were detected in 5 or less sites in each year of the study. This included the yellow-backed duiker (2 sites in 2014, 4 sites in 2021), side-striped jackal (4 sites in 2014, 2 sites in 2021), African civet (0 sites in 2014, 1 site in 2021), Egyptian mongoose (0 sites in 2014, 1 site in 2021), serval (0 sites in 2014, 1 site in 2021), and honey badger (1 site in 2014, 1 site in 2021).

Table 4: Probability of occupancy and detection (with standard error) for each individual species in 2021 using single-season occupancy models and combined ground and canopy camera trap detection histories.

Species	Probability of Occupancy	Probability of Detection
Allochrocebus lhoesti	0.845 (SE 0.0697)	0.518 (SE 0.0509)
Anomalurus derbianus	0.195 (SE 0.0858)	0.303 (SE 0.132)
Cercopithecus mitis	0.576 (SE 0.118)	0.334 (SE 0.0738)
Cricetomys gambianus	0.378 (SE 0.0678)	0.551 (SE 0.0733)
Funisciurus carruthersi	0.354 (SE 0.0749)	0.457 (SE 0.084)
Funisciurus pyrropus	0.346 (SE 0.0667)	0.543 (SE 0.0775)
Galago sp.	0.195 (SE 0.0739)	0.348 (SE 0.125)
Genetta servalina	0.242 (SE 0.135)	0.215 (SE 0.126)
Pan troglodytes	0.164 (SE 0.0632)	0.382 (SE 0.133)
Paraxerus boehmi	0.113 (SE 0.0403)	0.694 (SE 0.111)

Table 5: Probability of occupancy, colonization, extinction, and detection (with standard error) for ground-dwelling species between 2014 and 2021 using multi-season occupancy and ground camera trap data.

Species	2014 Occupancy	2021 Occupancy	Probability of Colonization	Probability of Extinction	Detection Probability
Atherurus africanus	0.463	0.365	0.283 (SE 0.098)	0.541 (SE 0.104)	0.563 (SE 0.0477)
Cephalophus nigrifrons	0.352	0.574	0.361 (SE 0.0816)	0.0346 (SE 0.0615)	0.697 (SE 0.0377)
Potamochoerus larvatus	0.168	0.166	0.102 (SE 0.0562)	0.518 (SE 0.245)	0.364 (SE 0.0912)
Carnivore *spp.*	0.139	0.139	0.162 (SE 0.116)	0.999 (SE 0.0159)	0.177 (SE 0.107)

Human Signs

Human signs were collected across all surveys, and in the table below (Table 6) we present encounter rates, or number of sightings per kilometer. Seventy observations were made in 2021 with an encounter rate of 0.146 per km, while 86 observations were made in 2014 with a lower encounter rate of 0.107 per km. Most human signs reduced both in number and encounter rate between years except for snares, which had twice as half of an encounter rate in 2021 than 2014 (Table 6).

Table 6 Encounter rates of human signs observed from transects in the 2009, 2014, and 2021 surveys.

Human sign	2009 survey (492km)		2014 survey (796km)		2021 survey (479km)	
	Obs	Enc rate	Obs	Enc rate	Obs	Enc rate
Wood cutting	8	0.016	18	0.023		0.000
Snares	3	0.006	40	0.05	62	0.129
People	-	0	7	0.009	0	0.000
Mining sites	-	0	9	0.011	4	0.008
Fires	-	0	3	0.004	1	0.002
Other	8	0.016	8	0.01	3	0.006
Total	19	0.038	85	0.107	70	0.146

DISCUSSION

Monitoring the population of wildlife in protected areas is an important component of protected area management. It is essential to assess whether the management of protected areas is achieving the objectives set for them, especially in the protected areas that are negatively affected by human activities, such as indiscriminate resource exploitation (including hunting) and land-cover change. It is important to document changes and trends in wildlife populations over time in order to provide updated scientific information necessary for adaptive management (Plumptre, 2000; White & Edwards A. Eds, 2000). We compared the abundance of mammals in Nyungwe National Park for 3 data sets (2009, 2014, and 2021) using 41 line transects throughout the park. We also assessed species richness using camera traps set on the ground and in trees for 2021 and compared occupancy as well as estimated probability of colonization and extinction between 2014 and 2021 using ground camera trap data. The use of line transects and camera traps to study mammal populations of tropical rain forests has some advantages. Most mammal species are nocturnal and inconspicuous (and sometimes rare) in the dense tropical forest while others are terrestrial or arboreal so that one single method can't be applied. Camera traps are used to document the presence and detection of many species, even of those that tend to flee or hide when sensing human presence (Moore et al., 2020).

Species richness and spatial distribution

The 2021 survey documented 28 individual species across the park with site species richness varying from 5 to 28 species. Species richness was higher along the main road, as

well as at sites in the north and west of the park whereas species richness was lowest in the south possibly explained by transboundary effects. High species richness in the northern section of the park could be explained by habitat restoration projects in this area, or continuous conservation activities such as tourism, research and monitoring, and law enforcement activities carried out in this part of the park. L'hoest monkeys were widely distributed throughout the park with an estimated occupancy probability of 85%. Colobus monkey (*Colobus angolensis ruwenzorii*) was detected in 5 sites while it was detected in 9 and 6 sites for 2009 and 2014 respectively. Some species were detected at 3 or less sites including owl-faced monkey (*Cercopithecus hamlyni*), large-spotted genet (*Genetta maculata*), woodland dormouse, Ruwenzori sun squirrel (*Heliosciurus ruwenzorii*), grey-cheeked mangabey (*Lophocebus albigena johnstoni*), African palm civet (*Nandinia binotata*), Potto (*Perodicticus ibeanus*), and the Central African oyan (*Poiana richardsonii*). It was not clear why species such as Side-striped Jackal (*Canis adustus*), which was detected in most of the forest fragments outside Nyungwe main forest (WCS 2021, unpublished data) was detected in only 2 sites in this survey. In general, species richness is associated with habitat heterogeneity, habitat disturbance, and species interaction (Fox and Fox, 2001). In previous species richness and distribution studies in NNP, higher species richness was associated with the decrease in poaching activity, nearest spatial features of the park such as tourist trails and lower elevation (Moore et al., 2016). These 3 surveys could not record species: leopard, forest hog and golden monkey which are believed to once have been in NNP but were not detected in the last 30 years.

Abundance and trends in primate populations over time

Density and abundance were based on chimpanzee nests, duiker dung, bushpig dung, and direct observations of blue monkey. Other species did not have enough data (less than 60 observations) required to estimate density using distance sampling.

Primates

Nyungwe National Park is known for its richness in primate species. Out of 13 species, 10 species (*Cercopithecus Ascanius*, *Cercopithecus hamlyni*, *Cercopithecus lhoesti*, *Cercopithecus mitis*, *Colobus angolensis*, *Galago matschiei*, *Galagoides thomasi*, *Lophocebus albigena*, *Pan troglodytes*, *and Perodicticus potto*) were recorded. Three species were not detected including Golden monkey, which was not detected in Nyungwe for the last 30 years, and Olive Baboon (*Papio anubis*)and Vervet Monkey (*Chlorocebus pygerythrus*), which tend to live at the edge and outside of Nyungwe forest (Chao et al., 2010).

Our results show that chimpanzee abundance has stayed fairly constant across the three surveys. The population of chimpanzee (*Pan troglodytes)* is estimated at an average of 398 individuals varying from 374 in 2009, 462 in 2014, and 358 individuals in 2021 in Nyungwe main forest. However, the point estimates have changed slightly between surveys, the 95% confidence intervals around these estimates overlap across all three years, which shows there is no significant difference between these estimates. There are about 35-40 individuals of chimpanzees found in Cyamudongo forest fragments, which forms part of NNP (Moore et al., 2018) making the total number of chimpanzees of 435 individuals on average (368 weaned chimpanzees and 66 chimpanzee with <4 years old). Considering an estimate of 19 chimpanzee individuals in Gishwati (Chancellor et al., 2012), and 204 weaned individuals in Kibira National Park (Hakizimana and Huynen, 2013), the population of chimpanzees in the Congo-Nile Divide is estimated at 591 weaned individuals. For long-term viability of chimpanzee population in this part of the Albertine Rift, intensive effort must be devoted to the chimpanzee's long-term conservation actions including transboundary collaboration, and habitat connectivity as well as implementing a monitoring program of chimpanzee populations to constitute a database, which would allow for detecting population trends.

The Blue monkey (*Cercopithecus mitis doggetti*) in these 3 surveys showed a decline in population from 10018 (2009) to 7308 (2021) individuals with an average population of 7250 (3854 – 13801) individuals. However, probability of occupancy (57.6%) was the second after L'hoest monkey (*Allochrocebus lhoesti*) explaining that this species occupies at least 50% of the park. It is not clear why the population of Blue monkey is declining in NNP. Although Blue monkey have a flexible, broad diet, they primarily eat ripe fruits and invertebrates (Butynski et al., 2020) suggesting that it is threatened by habitat loss and fragmentation throughout its geographical range (Butynski et al., 2020), which may be the reasons for population decline in Nyungwe National Park. It seems reasonable to assume that the removal of forest canopy because of forest fires in NNP over the last 20 years affected food (fruits) availability to this frugivorous *Cercopithecus mitis*. Butynski (2017) reported that food shortage, poaching, predation and disease can cause considerable declines in mammalian populations. Ranger-based monitoring data recorded 34 individuals dead during the period of 2 years (2016-2017). A specific objective research is suggested for better understanding of the causal effects on the blue monkey population decline in NNP.

Another primate species of interest in these surveys is L'Hoest's monkeys (*Allochrocebus lhoesti*). It is classified as Vulnerable on the IUCN Red List of threatened species, and its population is declining throughout its range (Ukizintambara, Olupot & Hart, 2019). The survey did not get enough observations to estimate the density and abundance of this

species because of their foraging behavior. L'Hoest's monkey are semi-terrestrial and travel long distances on the ground and forage mainly in lower forest strata (Kaplin and Moermond, 2000; Ukizintambara, Olupot & Hart, 2019; Ukizintambara, 2010) making it difficult to be detected by people walking along transect in dense and thick vegetation. However, using camera traps, many images (1,812 images) were recorded in 2021 allowing modeling of the probability of occupancy and detection. Our results suggest that probability of occupancy (85%) and probability of detection (51%) was the highest of the probability of occupancy of any other species recorded in this survey. This high probability of occupancy can be explained by high resilience to habitat modification. L'Hoest's monkey can adapt to forest edges and associated effects that result from changes in physical features of the habitat (Ukizintambara, 2010).

Antelopes and Pigs

Four species of antelopes and 2 species of pigs are believed to live in Nyungwe National Park (Chao et al., 2010; Storz, 1982). Black-fronted Duiker (*Cephalophus nigrifrons*), Yellow-backed Duiker (*Cephalophus silvicultor*), Bushbuck (*Tragelaphus scriptus*), Lestrade's Duiker (*Cephalophus weynsi lestradei*), and Bushpig (*Potamochoerus larvatus*) were detected in these surveys and are widely distributed primarily in the eastern and northern part of the park. Giant Forest Hog (*Hylochoerus meinertzhageni*) was not recorded, and it has possibly disappeared (locally vanished). From both line transect and camera trap data, it appears there has been a slight increase of duiker species across the surveys; however, there is uncertainty in the estimates based on the lower number of detections of dung in the first two surveys compared to the 2021 survey. Based on the models, the probability of detection increased greatly between the first two surveys compared to the 2021 survey, and thus the abundance estimate is more precise for 2021with population size estimated at 3,781 (2156 - 6621) individuals with a density of 3.9 (2.23 – 6.83) individuals per kilometer squared. Only Black-fronted Duiker had enough data to model probability of occupancy (Ψ = 0.352 for 2014 and Ψ = 0.574 for 2021) and probability of detection individually. Increase in duiker population in NNP was reported by (O'Brien et al., 2019) and this trend can be explained by conservation activities, which reduces poaching activity and habitat recovery from bushfires.

Abundance of bushpig has slightly declined across the three surveys, although there is significant overlap between the 95% confidence intervals for the three years. There is a lack of precision in these estimates as there are few bushpig dung detections in some surveys. Multi-season occupancy models for 2014 and 2021 showed higher probability of extinction (0.518) with detection probability of 0.364. The bushpig is the largest mammal available in the NNP and regularly hunted (Chao et al., 2010) and at least 12 bushpig

carcasses were recorded by rangers at their daily park protection patrols in 2016-2017 suggesting that this species is still threatened by poaching activities.

Carnivores

Ten species of carnivores were recorded: *Canis adustus*, *Civettictis civetta*, *Genetta maculate*, *Genetta servalina*, *Herpestes ichneumon*, *Herpestes sanguineus*, *Leptailurus serval*, *Mellivora capensis*, *Nandinia binotata*, *and Poiana richardsonii*. Carnivores are mostly solitary, cryptic and nocturnal, which explains the low number of direct observations during daytime walking. Therefore, we used indirect observation (dung) to estimate their encounter rates. There were very low observations of carnivore (<15) for 2014 and 2021) thus, we were not able to estimate density and abundance of carnivores. An average encounter rate of carnivores was relatively low and declined in these surveys varying from 0.128 (2009) to 0.029 (2021) and were predominantly found in central and north parts of the park. Conversely, the 420 photographs of carnivores obtained in the 2014 camera trapping survey are a clear indication of the potentials of this method to survey nocturnal and more secretive species.

Rodents and Squirrels

We recorded 8 species of rodent: *Anomalurus derbianus*, *Atherurus africanus*, *Cricetomys gambianus*, *Funisciurus carruthersi*, *Funisciurus pyrropus*, *Heliosciurus ruwenzorii*, *Paraxerus alexandri and Paraxerus boehmi*. Two species, *Atherurus africanus* and *Cricetomys gambianus* have been targeted for poaching in NNP (Chao et al., 2010).

Squirrels were not recorded in 2009 survey and none of them have data to estimate density/abundance. Instead, we used camera trap images to estimate probability of occupancy and detection for individual species. It is not surprising that probability of occupancy of *Atherurus africanus* decreased with probability of extinction of 0.541 explaining that poaching activities continue to target rodents in NNP. Data from ranger-based monitoring recorded at least 377 carcasses of rodents from snares in 2 years period (2016-2017). Based on 2014 and 2021 data, squirrels were more detected in the western and central parts of the park.

Human signs

The major threats to biodiversity in Nyungwe National Park are animal poaching, tree harvesting, mining (gold and coltan), and wildfires (Chao et al., 2010). Most observations of human sign during the 2009, 2014, and 2021 surveys belonged to the following

categories: wood cutting, snares, people, and mining sites. A general category of "other" included rarer observations such as sawing, poachers' camps, fields etc. Overall, there was a sharp increase in encounter rate of human signs from 2009 to 2021. Poaching was on the increases by the time of the 2021 survey. Encounter rates of snares doubled for the period from 2015 to 2021with encounter rates of 0.05 in 2014 and 0.129 snares/km in 2021. In addition, the survey team removed about 268 snares and encountered 38 animal carcasses when moving between transects. Encounter rates of snare removal in the park was 0.367 snares/km walked by rangers (Chao et al., 2010), and 4.24 poaching related threats were detected per site (1 km^2) for 2006 – 2016 period (Moore et al., 2017). Hunting is mostly carried out using traditional methods, either with spears or snares targeting mammals or ground dwelling birds such as francolins. Most hunting is still believed to be carried out for subsistence needs although there is evidence that it is sometimes sold in local markets, and it is due to lack or limited alternative income generating opportunities among communities living adjacent to the park boundary (Chao et al., 2010). Although the larger remaining mammals such as bushpig are targeted, most snares found are targeting smaller species such as the pouched rats, squirrels, and porcupines. There is evidence of severe decline and scarcity of medium and large sized mammals such as bush pig and porcupine in the forest, as has been reported based on the results of 2009-2014-2021 surveys.

MANAGEMENT IMPLICATIONS

The major challenge for conservation of wildlife populations in Nyungwe National Park today remains the lack of enough data to estimate their densities and abundances. Although the efforts to study wildlife populations were made, only few species obtained data to estimate their abundance. Other species that might be of ecological importance such as carnivores, and other species which are listed on IUCN Red list of threatened species were recorded but with not enough data to estimate density and abundance either because they are rare, have a large home range, or are sensitive to cameras and other survey tools. First, we recommend further studies with higher sampling efforts (more transect visits, longer camera trapping at sites), and possibly the addition of new methodologies such as genetic sampling (DNA). Given that it is not possible to monitor all species, the emphasis should be put on larger-bodied animals (apes, duikers and monkeys), since these groups are a priority for many wildlife managers and researchers in African rain forests, and they tend to be a good index of the overall integrity and conservation status of a region. Second, habitat degradation (with no recovery) forms a second challenge to the conservation of this park. About 10% of Nyungwe's habitat was degraded by anthropogenic uncontrolled fires and the recovery of original forest is very slow.

Although WCS and RDB have made effort to restore the habitat in fire degraded areas through assisted natural forest regeneration (removal of obstacles to seed germination), restoration of forest in fire degraded areas should be and it is still a priority to enhance habitat recovery and connectivity. Third, illegal activities such as resource extraction (i..e, poaching, tree/bamboo cutting) should be minimized through improved law enforcement, conservation awareness campaigns, and community development projects. It is critical that the conservation approach can adapt to, and address the changing threats faced by the forest. The growing population and high levels of poverty combined with the possibility of a more variable climate that may affect the Nyungwe National Park in one way or another, conservation initiatives will need to not only address direct threats to the forest but also consider people's attitudes and values to tackle the underlying drivers of forest degradation and destruction.

CONCLUSION

Medium to large mammal surveys were carried out with the goal of getting detailed understanding of their population size, spatial distribution, and their population trends to inform adaptive management decision making of the Nyungwe National Park. We analyzed survey data for three years (2009, 2014, and 2021) to estimate density, abundance and population trends of chimpanzee populations and other medium and large-sized mammals in Nyungwe National Park. Data were collected using standardized line transects and camera trapping methodologies. All surveys were conducted in dry seasons between June and September. In total, 28 mammal species were recorded including 10 species of primates, 8 species of carnivorous, 4 species of ungulates and 1 species of pig. We estimated density and abundance of four species, which had sufficient data for analysis. We showed that chimpanzee populations stayed stable, duiker population increased whereas populations of bush pigs and blue monkey declined over the survey period. Similarly, we noted that *Atherurus africanus*, and carnivore species probability of occupancy decreased over this period. However, there is a lack of precision in these estimates as the sample size is small and there is overlap in 95% confidence intervals across the three surveys. Having the stable population of the Endangered eastern chimpanzee (*Pan troglodytes schweinfurthii*), and increased population of duiker, especially *Cepahlophus nigrifrons*, as well as high probability of occupancy of *Allochrocebus lhoesti* is good news/indicator of conservation achievement for this biodiversity rich national park. Although habitat might be recovering from bush fires, poaching activities are on rise and might be the cause of declining populations of species such as bushpig and porcupine. Improved law enforcement should be put forward to deter poaching activities. However, there was a problem with lack of data for some species, allowing for the calculating of encounter rate but not density or abundance. In order to tackle this problem, future surveys should involve more transect walks to increase the number of detections for different species and longer periods with camera traps active in the forest. Camera traps in particular are more likely to detect rare species like carnivores, for which little is currently known in terms of their occupancy around the park.

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