Imperial College London

Determinants of spatial patterns of human activity in Bwindi Impenetrable National Park

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August 2017

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A thesis submitted for the partial fulfilment of the requirements for the degree of Master of Science at Imperial College London
Submitted for the MSc in Conservation Science (CID: 00884286)

Declaration of Own Work

I declare that this thesis, "Determinants of spatial patterns of human activity in Bwindi Impenetrable National Park" is entirely my own work, and that where material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

Signature 

Table of Contents

Photo: Bwindi Impenetrable National Park border and tea plantation. F. Olsthoorn 2017

Word count: 6000

List of acronyms

BDP	Batwa Development Program
BINP	Bwindi Impenetrable National Park
CTPH	Conservation Through Public Health
DBH	Diameter at breast height
GPS	Global Positioning System
ITFC	Institute of Tropical Forest Conservation
KII	Key informant interviews
MGVP	Mountain Gorilla Veterinary Project
MUZ	Multiple Use Zone
PME	Participatory mapping exercise
QGIS	Quantum Geographic Information System
URP	Uplift the Rural Poor
UWA	Uganda Wildlife Authority

Acknowledgments

I thank Dr. E.J. Milner-Gulland for accepting me as a student to work on this project and for her perceptive and insightful guidance. I thank Dr. Marcus Rowcliffe for accepting to supervise this project and for his patient and devoted guidance. I thank Dr. Henry Travers for his tireless efforts in creating the best conditions possible for fieldwork, his valuable guidance and his excellent company.

I thank Gladys Kalema-Zikusoka for her guidance, advice and encouragements in preparation of and during my project and for hosting me at CTPH in Entebbe and at the Gorilla Conservation Camp in Buhoma. I thank Rose Mugide and Richard Bagyenyi for providing logistical support, Amy and Shaban for welcoming me in Uganda and in their home, Alex Ngabirano and Enos Nahabwe for going out of their way to help me during fieldwork, Solomon Ngabirano for his daily support and for being an amazing host, cook and bird guide at the Gorilla Conservation Camp, and Apophia, Naomi, Thomas and Saul for their daily help at the Camp.

I thank the Uganda Wildlife Authority for giving permission to carry out fieldwork, I thank Raymond Kato for his support during the research and Samsom Luanga, for being a devoted researcher and not missing a single day during the long forest surveys.

I thank of course my field assistant Christopher Byaruhanga without whom this project would not have been possible. I thank all the UWA respondents and resident respondents for taking the time to share their thoughts with me, their participation was invaluable to this project.

I thank Moses Musiimenta for his logistical support and for being a safe motorcycle rider, I thank Richard from ITFC for driving us safely and tracking us down after forest surveys.

I thank Dr. Julia Baker for all her advice on conducting research in Uganda, devoting her time to help me and putting me in touch with valuable connections. I thank Dr. Medard Twinamatsiko for providing me with insights on conducting social research in Bwindi and Prof. Robert Bitariho for his advice on MUZs, I thank Dr. William Olupot for taking time to write and meet me to give advice on conducting forest surveys in Bwindi. I thank Mariel Harrison for her advice on conducting research in Bwindi. I thank Andrew Kirkby for his advice on finding shapefiles for GIS. I thank Dr. Andrew Knight for his tips on analysing social data. I thank Ans Vercammen for her help in statistics

I thank Victoria Griffiths for advising me on conducting social research in Uganda. I thank Dr. Jamie Samson for his help in statistics. I thank the whole ICCS team in Oxford for warmly welcoming me and supporting me in writing up the project.

I thank my friends for keeping me virtual company during fieldwork and providing continuous moral support, listening to endless stories about slippery terrain and data analysis. I look up to and thank my mother, my brother and my grandparents for being sources of inspiration to me and unconditionally and continually supporting me in every way possible, they are the reason I can pursue a career in a field I love and I am eternally grateful for that.

I thank Imperial College London and the Darwin Initiative for funding this project.

ABSTRACT

As protected area (PA) management goals are shifting from strict protection to sustainable management (McShane & Wells 2004; Brockington & Igoe 2006), measuring the threat status of PAs has become crucial to assess the effectiveness of these management strategies (Salafsky & Margoluis 1999). One of these threats is human activity, including access and resource use. In this study I examined the types, levels and four observable factors that influence human activity in Bwindi Impenetrable Park by combining respondent data (participatory mapping exercises and key informant interviews) with observational data (surveys carried out on the boundary of BINP and existing ranger patrol data). The four factors are (1) variance of elevation (2) legal trails, a proxy for ranger activity (3) presence of Mauritius thorn, a shrub planted at the boundary to prevent animals from crop raiding (4) the presence of Multiple Use Zone, areas where residents can access resources legally. Combining results from the different data sources, it is apparent that wood and bushmeat are the most extracted resources from the Park, and collection of medicinal and edible plants, weaving materials, honey, water and grazing also take place. Forest surveys, which allowed to quantify mostly wood-based resource extraction showed a frequency of 11 resource use instances per km on the boundary, 10.5 trails per km on the boundary with 71 instances of resource use per km trail, Regression analysis of the four above-mentioned factors showed that resource extraction on the boundary was inversely correlated with the presence of legal trails (p=0.022) and also negatively associated with Mauritius thorn (p=0.053), which calls for more attention of these factors in future management practices. Respondent data showed discrepancies between solutions proposed by respondents (more park benefits) and authorities (more awareness on existing benefits), which calls for better tailoring of interventions involving local residents.

KEYWORDS

mixed method, mountain gorillas, natural resource use, poverty, protected area management, tropical forest, Uganda

INTRODUCTION

PA management is shifting from traditional fortress conservation to more inclusive approaches combining conservation and development, with the goal to achieve sustainable management (McShane & Wells 2004; Brockington & Igoe 2006). Measuring the threat status of protected areas is crucial to assess the effectiveness of these management strategies (Margoluis & Salafsky 1998; Babu & Reidhead 2000; Hockings 2003). One of these threats is human activity (legal or illegal access and resource use), however, it can be difficult to measure, especially when it is illegal or sensitive (Nuno & St. John 2014). In this paper I use a mixed-method approach to measure levels of human activity in Bwindi Impenetrable National Park (BINP) to draw recommendations on its management.

Bwindi Impenetrable National Park is one of the most biodiverse places in Uganda and it harbours half of the world's population of mountain gorillas (*Gorilla beringei beringei*) (Robbins et al. 2011). It was gazetted as a National Park in 1991 and made a UNESCO World Heritage Site in 1994 (UWA 2014). However, the strict protection of the forest has created many conflicts with the residents of surrounding areas who depend on forest resources. As a result, resource extraction by residents has continued illegally (Wild & Mutebi 1996; Baker et al. 2012). The Uganda Wildlife Authority (UWA), which is responsible for the management of BINP, implements a programme of law enforcement through ranger patrols and a number of interventions that are meant to improve residents' attitudes and reduce dependence on forest resources. These include (1) the employment of residents as a ranger or porter (2) the sharing of revenue from gorilla permits and park entrance fees to fund development projects for residents surrounding the park (3) the establishment of Multiple Resource Use Zones (MUZ) in which residents with permits are granted access to extract medicinal plants, basketry materials and honey on a limited amount of days per year, accompanied by rangers (4) the mitigation of human-wildlife conflict through the training of Human-Gorilla guards (HUGOs) who chase away gorillas that raid crops and the planting of Mauritius thorn (*Caesalpinia decapetala*) along the park boundary, a thorny bush

56 that, once it is fully grown, is supposed to prevent animals from coming out of the park to
57 village land to raid crops (UWA 2014). A range of NGOs also implement conservation
58 activities relating to human health and development, e.g. Uplift the Rural Poor (URP) and
59 the Batwa Development Program (BDP), activities relating to conservation, e.g. the
60 Mountain Gorilla Veterinary Project (MGVP) and integrated conservation and development,
61 e.g. Conservation Through Public Health (CTPH) (Baker et al. 2013; UWA 2014).
62
63 Previous studies using observational data (Olupot et al. 2009) and respondent data (e.g.
64 Harrison et al. 2015) have shown that despite law enforcement and community-based
65 interventions, dependence on forest resources including poaching, wood harvesting, plant
66 collection and the creation of illegal access routes remains high. Building on these previous
67 efforts, I aim to I aim to draw a complete picture of human activity by combining different
68 data sources to draw recommendations on rendering human activity more sustainable in
69 BINP by answering the following questions:
70 (1) What are the different types of human activity taking place in BINP?
71 (2) What are the levels of human activity taking place in BINP?
72 (3) What factors influence human activity and resource use in BINP?
73 (4) How can human activity in BINP be made more sustainable?
74 For my third research question, I chose four factors that I hypothesised could influence
75 human activity and that can be drawn from both respondent and observational data to
76 allow comparison (Figure 1).

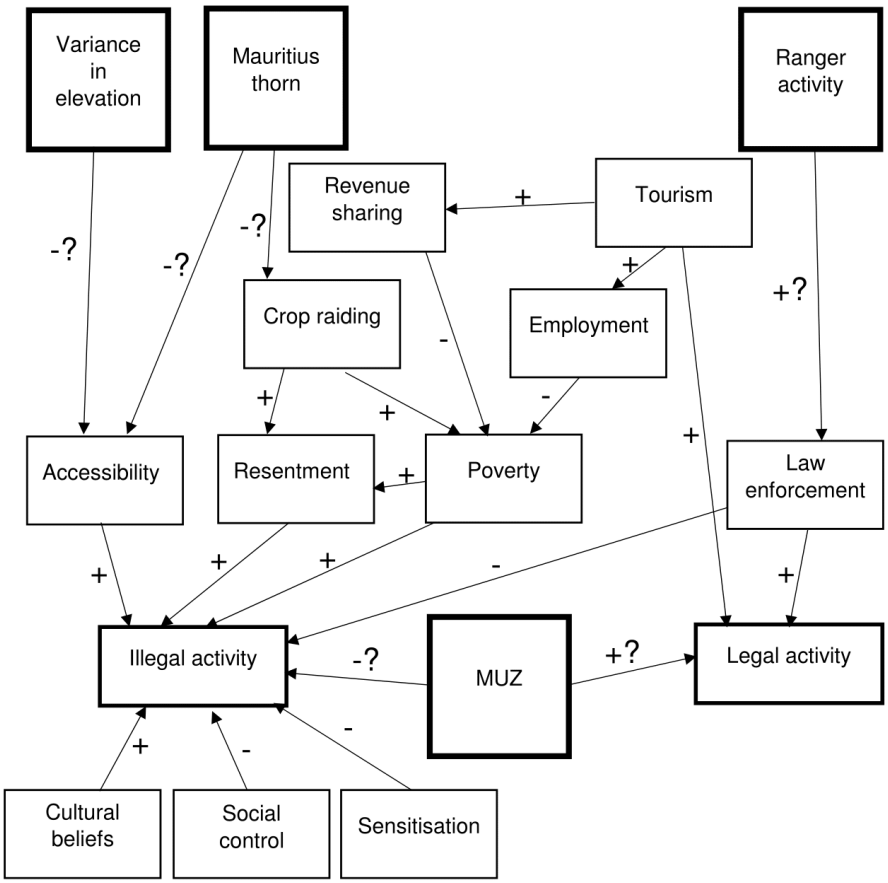


Figure 1*: A conceptual framework on factors that influence human activity in BINP. Factors that have previously shown to influence human activity in BINP by Harrison et al (2015), are integrated with four observable factors that I assessed in this study as a means to test whether the combination of observational data and respondent data can increase our understanding of human activity These are variance of elevation, presence of Maruitius thorn, ranger activity and presence of a Multiple Use Zone (MUZ). The arrows represent the direction of the relationships I hypothesise and are further explained in Table 1b.*

METHODS

This study is in compliance with the ethics requirements of Imperial College London and was undertaken with permission of the Uganda Wildlife Authority (see Supporting Information).

Study area

Bwindi Impenetrable National Park is situated in the Southwest of Uganda, bordering the Democratic Republic of the Congo (0˚53' to 1˚8' South; 29˚35' to 29˚53' East). It covers 321 km^2 and is one of the few extended areas of Afromontane forest on the African continent. With its altitude ranging between 1990 and 2607 meters, it is a combination of medium altitude moist forest and high altitude forest (UWA 2014). It forms a significant part of the Albertine Rift ecosystem and harbours exceptional biodiversity, including half of the entire population of the critically endangered mountain gorilla (*Gorilla beringei beringei*) (UWA 2014) .

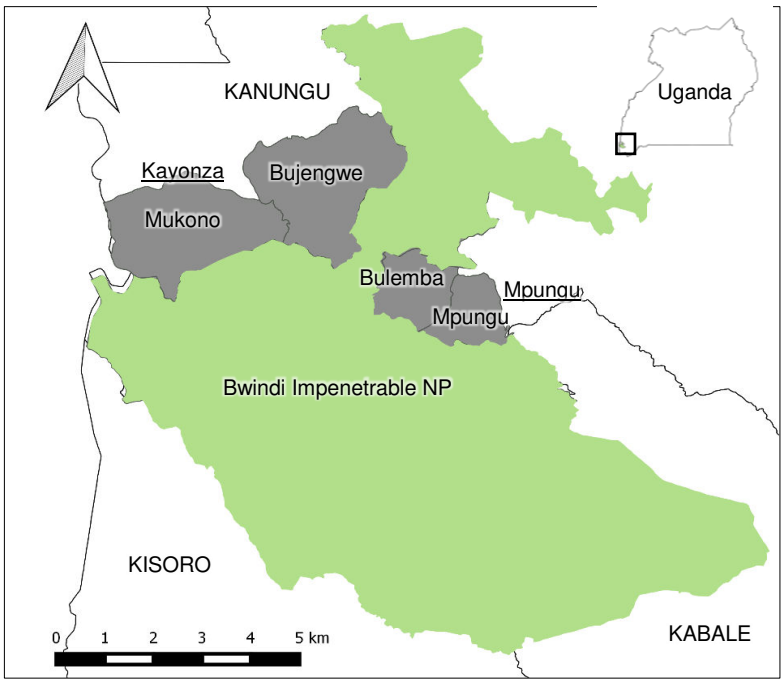


***Figure 2**: Study area: Bwindi Impenetrable National Park, Uganda*

The park is spread over the Kabale, Kanungu and Kisoro districts of Uganda. The park is surrounded by 21 parishes – with around 10 villages in each parish, which are among the poorest and most highly populated in the country (Uganda Bureau of Statistics 2016). The

main ethnic group is the Bakiga. The Bakiga live in villages and ach village has an elected chair who is responsible for liaising with the government and other authorities. All Bakiga adults are part of one of the stretcher groups in the village, a locally-led governance system with by-laws which was originally created for local health care and insurance (Katabarwa 1999) but have evolved to include conservation education and sometimes a fining system for trespassers to BINP (C. Byaruhanga, personal communication). There is also a Batwa minority, former forest dwellers who were evicted after gazettement of the park and now live in settlements surrounding the park (Wild & Mutebi 1996). The study took place in Kanungu district, in two parishes in Kayonza subcounty, Mukono and Bujengwe, and two parishes in the Mpungu subcounty, Bulemba and Mpungu (Figure 2)

.

Methodological approach

We used a mixed method approach, collecting observational and respondent data to answer the research questions outlined in the introduction (also see Table 1a). Respondent data collection consisted of examining patrol data from 2016 and conducting participatory mapping exercises (PMEs) with residents and key informant interviews (KIIs) with leaders among the resident population and UWA members. The aim of KIIs and PMEs was to obtain data on the different types of human activities that take place in the park, different deterring and inciting factors of these activities and possible solutions to make human activity more sustainable. Observational data collection consisted of conducting forest surveys on the village-park boundary of BINP, with the purpose of quantifying and mapping human activity (trails and instances of resource use) and four different observable factors that might impact them. A summary of these observable factors along with the hypotheses for each can be found in Table 1b. The mixed method approach allowed me to compare the results generated from the two sources of data to build a clearer picture of human activity in the park.

128 ***Table 1a:*** *Methods of analysis for each research subject, derived from the four research*

129 *questions*

Subject	Method	
	Respondent data	*Observational data*
(1) Types of human activity	Types of human activity as mentioned by respondents	-
(2) Levels of human activity	Frequency of mention of different resources	Average resource density Average trail density Unit of measurement: - Boundary segment
(3) Four factors that impact human activity • Ranger activity • Mauritius thorn • Variance of elevation • MUZ	Mention of these factors by respondents	Three regression models: - Resource use on the boundary - Amount of trails by residents - Resource use on trails - Predictor variables*: • Ranger activity • Mauritius thorn • Variance of elevation • MUZ Unit of measurement: - Boundary segment
(4) Recommendations	Recommendations as mentioned by respondents	Recommendations based on factors that influence human activities

130 *see Table 1b for hypotheses

131

132 ***Table 1b:*** *Variables that are hypothesized to have an impact on the level of human*

133 *activity*

Variable	Measurement	Hypothesis	Explanation
Ranger activity	Presence –absence of legal trails	Illegal activity lower in areas with ranger activity	Fear of arrest has been shown to be a deterring factor for residents to enter the park (Harrison et al. 2015)
Mauritius thorn	Presence absence of successful Mauritius thorn (higher than 1.5 meters)	Illegal activity lower in areas with successful Mauritius thorn	Succesful Mauritius thorn could impede access to the park or reduce resentment towards the park, reducing illegal activities
Variance of elevation	Variance of elevation	Illegal activities lower in areas with large variance of elevation	Steep terrain could impede access to the park
Multiple Resource Use Zone (MUZ)	Presence of MUZ	Activities lower in area with MUZ	MUZs were established to make resource use more sustainable (Wild & Mutebi 1996)

134

135

Collection and analysis of observational data

I used two sources of observational data, existing patrol data and forest surveys. For the forest surveys, we first performed a pilot on 26 May in Karangara parish and we performed the forest surveys for the research over 15 days between 30 May and 5 July 2017, with a team of four (two UWA rangers, one field assistant and I). This consisted of walking along the entire boundary of Mpungu, Bulemba, Mukono and Bujengwe parishes, a total of 42181 m. The unit of measurement were boundary segments. I divided the boundary into a total of 81 segments of approximately 600m, stratified by parish, by tracking the distance travelled on a handheld Global Positioning System (GPS) device (Garmin GPSMAP 64S). We recorded every trail along the boundary, and carried out sampling along all trails in every other segment. We measured the length of each trail with a tape roll and followed for 300 m or, if shorter than 300 m, until the end of the trail. I chose 300 m as a previous study has shown that most resource use takes place between the boundary and 300 m into the park (Olupot et al. 2009) (Figure 3). We recorded all instances of resource use along the whole boundary and also on trails in every other segment. These included cut timber (indicated by cutting of large trees – estimated diameter at breast height (edbh) >30cm), cutting of poles (trees or branches edbh 5-30 cm), cut firewood (indicated by cutting of dry trees or branches), cutting of saplings (edbh <5 cm), cut lianas, grazing (indicated by trampled vegetation, livestock and/or their dung), active snare, water collection (indicated by the presence of a container next to a water source or a pipe placed in the water to aid water collection or drinking livestock), honey collection (indicated by a burnt hollow branch or trunk) and plant collection (indicated by removal of the part of a plant e.g. the bark of a tree). We did not record cuttings that were not removed from the forest as we considered it was not used as a resource, nor cuttings older than 10 years (estimated from tump decay) due to difficulties with evaluating whether an old stump is cut or broken.

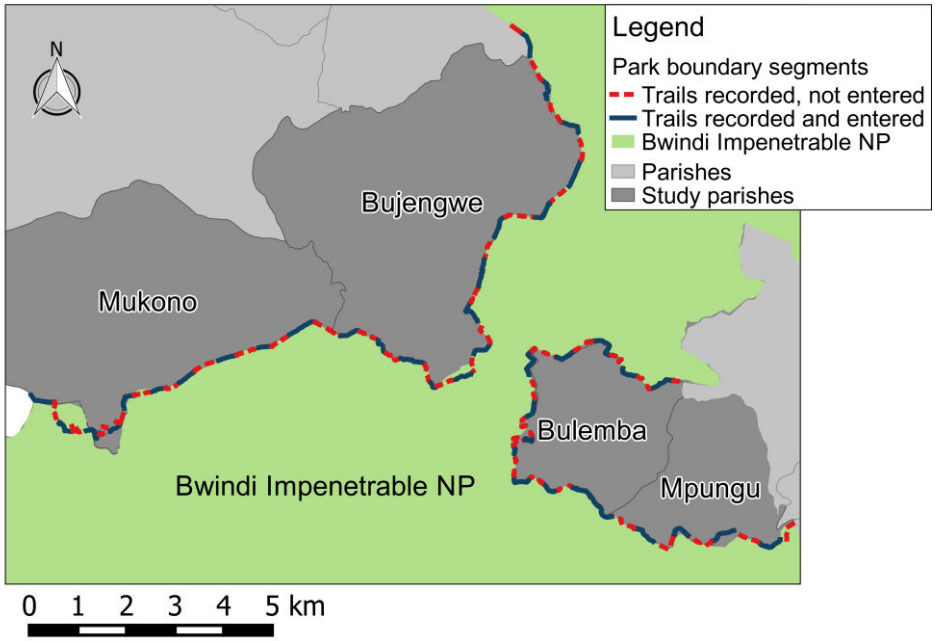


Figure 3: *Observational data collection method. We walked and recorded trails along the entire boundary and entered trails along every other boundary segment as shown on the map.*

Legal trails were identified with the help of the present rangers and included trails made by or with the authorisation of UWA for the purpose of crossing, gorilla tracking, tourism or research, We labelled every trail that did not fall into these categories as illegal. We continually estimated the height of Mauritius thorn along the boundary and took waypoints at the start and the end of zones with Mauritius thorn higher than 1.5 meters. I calculated variance of elevation for every segment from the elevation of all waypoints taken within a segment. I obtained information on the location of MUZs from the paper of Bitariho et al. (2016). I compiled GPS waypoint data in Microsoft Excel 2016. I produced maps and length measurements of boundary segments with Quantum Geographic Information System (QGIS), version 2.8.2. I produced graphs with IBM SPSS Statistics version 24. I performed statistical analysis with R version 3.4.0 (R Core Team 2017). I did group comparisons using Wilcoxon rank sum and Kruskal-Wallis tests for counts of resource use and trails. The count

177 data of resource use and trails had an over dispersed distribution (variance larger than
178 mean). I performed regression analysis with three negative binomial generalized linear
179 models using the MASS package (Venables & Ripley 2002) (Table 1). The independent
180 variables for each of the models were presence of multiple resource zone, presence of
181 successful Mauritius thorn, variance of elevation (steepness of terrain), presence of legal
182 trails (ranger activity) and an offset for segment length, as not all segments had the same
183 length due to imperfect recording by the GPS.
184
185 I obtained patrol data of 2016 from the UWA warden for Monitoring and Research at BINP.
186 As I did not obtain information on the effort and detailed methods of patrols, I used this data
187 by drawing proportions of each type of resource use from the total amount of recordings
188 and by mapping it for visual inspection.

189 **Collection and analysis of respondent data**

190 I carried out 20 participatory mapping exercises (PMEs) with residents, 16 key informant
191 interviews (KIIs) with residents and 4 KIIs with UWA staff members between 29 May and 7
192 July 2017, preceded by a pilot on 25 May 2017 in Karangara parish. I led the PMEs and
193 KIIs with residents in English, respondents spoke Rukiga and my field assistant did live
194 English-Rukiga and Rukiga-English translation. I conducted KIIs with UWA staff members
195 in English. I recorded and transcribed all PMEs and KIIs in English. An overview of the
196 sampling protocol, the PMEs and KIIs we conducted, my positionality statement following
197 the methods of Savin-Baden & Major (2012) and the PME and KII guides can be found in
198 the Supporting Information.

199 ***Participatory mapping exercises (PME)***

200 I randomly selected a village in each of the four parishes of the study area where we
201 conducted a PME with Bakiga men, women and mixed-sex stretcher groups. In Mpungu,
202 we also conducted a PME with Bakiga men and women who were part of the MUZ

203 programme. Additionally, we conducted PMEs in the three Batwa settlements in the study
204 area, one with men and one with women.

205 ***Key informant interviews (KII)***

206 We conducted KIIs in the four villages with the village chairman, a stretcher group chairman
207 and the HUGO chairman where HUGOs were present (Mukono and Bujengwe). We also
208 conducted KIIs with the leaders of the three Batwa settlements. Finally, I conducted KIIs
209 with four UWA wardens, two UWA rangers and one former UWA ranger, all in English. I
210 analysed the PMEs and KIIs using a 6-step thematic analysis following the methods of
211 Braun & Clarke (2008) using NVivo Starter software, version 11.

RESULTS

What are the different types of human activity taking place in BINP?

Illegal activities

The management plan of BINP states that no harvesting by residents is permitted outside of MUZs (UWA 2014). The resources that are harvested illegally as mentioned by respondents are outlined below.

Trees

Many local resources are derived from wood. Firewood and charcoal serve as fuel for cooking and baking bricks. Residents use timber from pit sawn trees to build houses and make doors, furniture, beer boats – tubs used to make banana beer – and coffins. Middle-sized trees form building poles and saplings, which are used as walking sticks and as stakes for climbing beans, a common crop in the area. Trees are also ground into medicine. A few residents own eucalyptus and pine tree plantations but trees from the park are more abundant and considered to be of better quality. Although not a tangible resource, in half of the KIIs and PMEs, respondents indicated that the park or trees in general have a role in climate regulation, providing shelter from the wind, rain formation and/or shade provision.

Animals

Animal harvesting consists of hunting and fishing. Hunting happens with spears and dogs or by laying snares. Bushmeat and fish are not only appreciated for their superior taste but also for their medicinal properties. As the animals in the forest feed on medicinal plants, their flesh is believed to be more nutritious, thus curing and strengthening people.

Weaving materials

Weaving materials include sedges to make mats for drying crops and different vines to braid baskets used for crop collection, storage and eating. Sedges can be found on village land but most basketry materials come from BINP.

Medicinal plants

Medicinal plants are made from the roots, stems or leaves of certain herbaceous plants, shrubs or trees. People use them to treat a wide array of conditions from intestinal worms, toothaches and eye problems to more serious conditions like pneumonia, malaria, cervical cancer and evil spirits. Although most residents know the basic medicinal plants, there are specialists who know where to find different medicinal plants in the park. Some medicinal plants can be found on village land and are used for first aid and emergencies, most medicinal plants are in BINP however. Some are abundant and near the edge, but others are more scarce and require hours of searching in the park. Although some diseases are treated in hospitals, others are specifically treated with medicinal plants.

Honey

Forest honey from BINP is harvested in two ways: wild honey from hollow trunks and stingless bee honey from the ground. Wild honey is used to treat burns, fractures, lung and throat problems and ulcers.

Water

Water from streams that run through BINP is used for consumption, washing livestock or letting livestock drink and washing clothes.

Legal activities

Legal activities include extracting resources from the MUZ in the presence of UWA rangers, and any other entrance to the park by or in the presence of rangers that is authorised by UWA.

Multiple Use Zones (MUZ)

There is one MUZ in the study area where, under a temporary Memorandum of Understanding (MoU), village residents with permits, MUZ users, can extract a limited amount of medicinal plants and weaving materials in the company of rangers from a list of species created by UWA and ITFC (Institute of Tropical Forest Conservation). The MUZ user respondents said the list of resources included some but not all important resources. Notably, baskets for plucking tea – the most important cash crop in the area - are woven from slow growing vines and are therefore not in the agreement. UWA sets predetermined MUZ harvest days and can grant additional days on demand.

Tourism, patrolling and research

UWA carries out tourism activities in the form of guided hikes and gorilla tracking through the park. A group of trackers locates habituated gorilla groups in the park every day by following ranger trails and cutting their way through the park to follow gorilla tracks (personal observation). Habituated gorilla groups can be visited by one group of tourists per day. UWA respondents indicated that patrols happen daily at random predetermined points in the forest. The coverage of each patrol depends on a schedule with predetermined locations to patrol and the availability of rangers on that day. Occasionally, rangers on patrol camp in the park. Research on water monitoring, climate change and mammals is carried out by UWA and additional research takes place in collaboration with universities and NGOs including for example ITFC and CTPH.

What are the levels of human activity taking place in BINP?

Trails

The average density of trails originating from the boundary was 10.5 trails per kilometre (SD=11.2). This includes legal trails, however almost all of the trails we encountered were illegal trails (Figure 4 a and b). Legal trails were wider and easier to access than illegal trails as they were well maintained with cuttings of vegetation on the side. There was no significant difference in trail density in the different subcounties (Wilcoxon rank sum, W=838, p=0.605) or parishes (Kruskal-Wallis, X^2=4.214, p=0.239).

Resource use

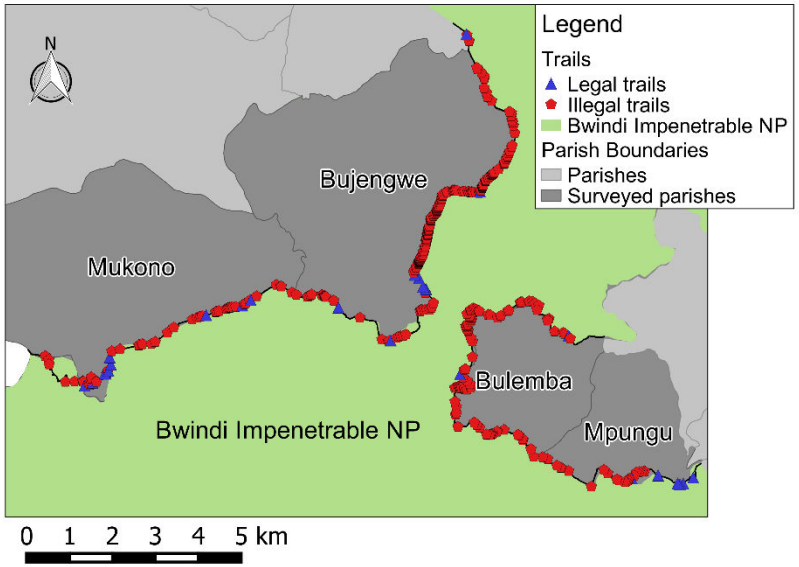
The density of instances of resource use was almost seven times higher on trails than on the park-village boundary (see Figure 4 c and d). Instances of resource use took place on both legal and illegal trails and were typically clustered. There was no significant difference of resource use on the boundary in subcounties (Wilcoxon rank sum, W=674, p=0.287) or parishes (Kruskal-Wallis, X^2=4.95, p=0.177), nor for resource use on the trails for subcounty (Wilcoxon rank sum, W=214.5, p=0.543) or parishes (Kruskal-Wallis, X^2=2.1306, p=0.344).

When looking at each resource separately (

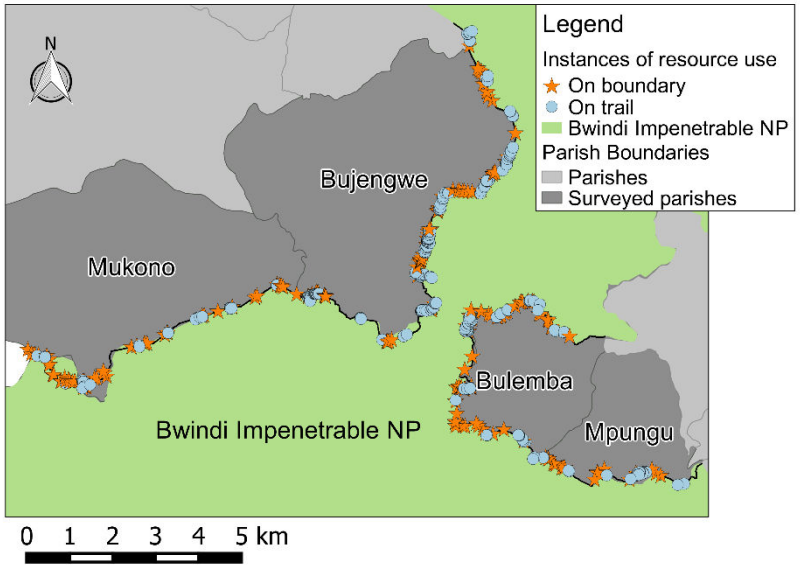
Table ***2*** and Supporting Information for specific species mentioned, pictures of resource use instances and a map of patrol data), a large majority of the resource uses we encountered was cut wood and this was also the resource that respondents mentioned most often. For the remainder of the resources there is some discrepancy between the respondent and observational data. Grazing was the second most frequently observed resource use in forest surveys and was also found on patrols but respondents did not mention it. The distribution of grazing sites was patchy, with one large patch in the North of Bujengwe parish. We observed severe trampling along the boundary and on trails as well as a heard of livestock in the park (see pictures in Supporting Information).

305

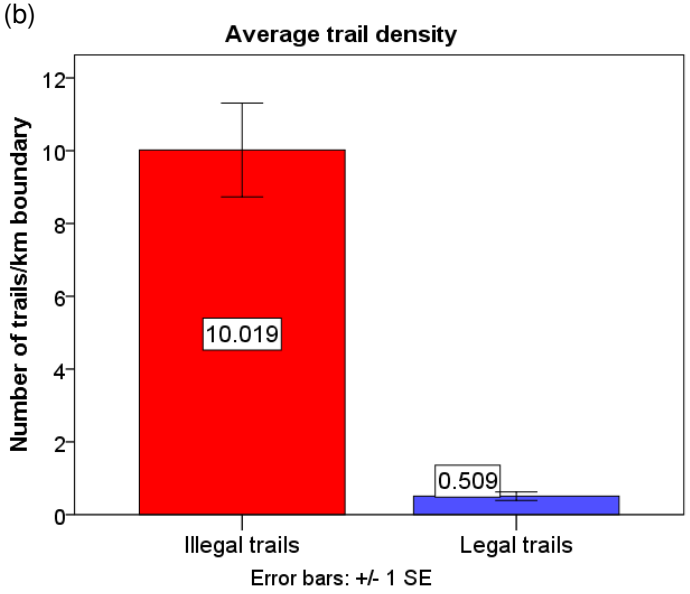
(a)


N
Legend
Trails
Legal trails
Illegal trails
Bwindi Impenetrable NP
Parish Boundaries
Parishes
Surveyed parishes
Bujengwe
Mukono
Bulemba
Mpungu
Bwindi Impenetrable NP
0 1 2 3 4 5 km

(c)


N
Legend
Instances of resource use
On boundary
On trail
Bwindi Impenetrable NP
Parish Boundaries
Parishes
Surveyed parishes
Bujengwe
Mukono
Bulemba
Mpungu
Bwindi Impenetrable NP
0 1 2 3 4 5 km

(b)


Average trail density
Number of trails/km boundary
12
10
8
6
4
2
0
10.019
0.509
Illegal trails
Legal trails
Error bars: +/- 1 SE

(d)

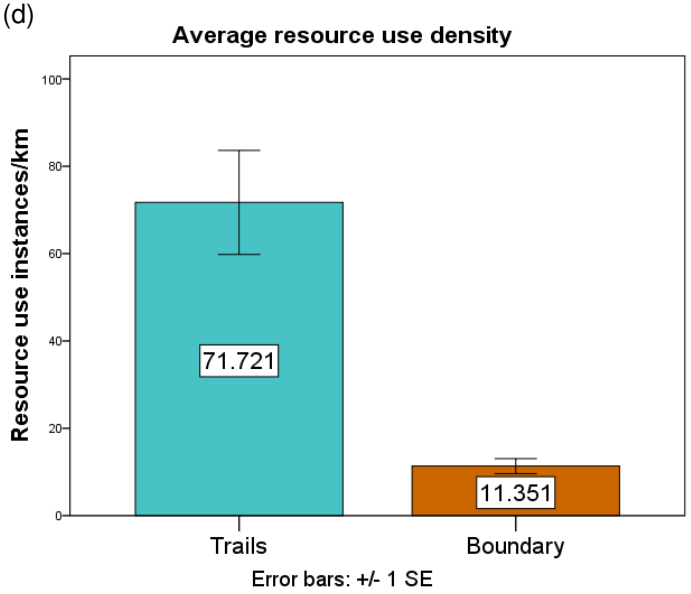

Average resource use density
Resource use instances/km
100
80
60
40
20
0
71.721
11.351
Trails
Boundary
Error bars: +/- 1 SE

Figure 4: Density of trails and resource use instances

(a) Map of illegal and legal trails originating from the park-village boundary (b) Density of illegal and legal trails (c) Map of resource use density on the park-village boundary and on trails originating from the park-village boundary (d) Density of resource use instances on the park-village boundary (instances of resource use per km boundary) on and on trails (instances of resource use per km trail).

310

311 ***Table 2**: Results on frequency of resource use from observational and respondent data*

	Observational data			Respondent data
	Forest surveys		Patrol data	
	Density of resource use on boundary (resource use/km boundary)	Density of resource use on trails (resource use/km trail)	Percentage of total observations	Frequency of respondents mentioning the resource
Wood	20.431	95.313		
Firewood	*10.331*	*52.478*		
Sapling	*4.724*	*18.966*		
Pole	*4.396*	*20.964*	14%	Very frequently
Timber	*0.183*	*0.642*		
Charcoal	*0.051*	*0.341*		
Beer boat	*0.033*	*0.070*		
Animal protein	*0.019*	0.139		
Bushmeat	0.019	0.139	82%	Very frequently
Fish	-	-	0%	
Weaving materials	0.255	0.890	0.5%	Frequently
Medicinal plants	0.036	0.174	0%	Frequently
Honey	0.033	0.070	0.5%	Sometimes
Water	0.148	0.473		
Water collection	*0.107*	*0.372*	0%	Sometimes
Livestock drinking	*0.041*	*0.101*		
Edible plants	-	-		Sometimes
Grazing	0.957	3.281	3%	Never

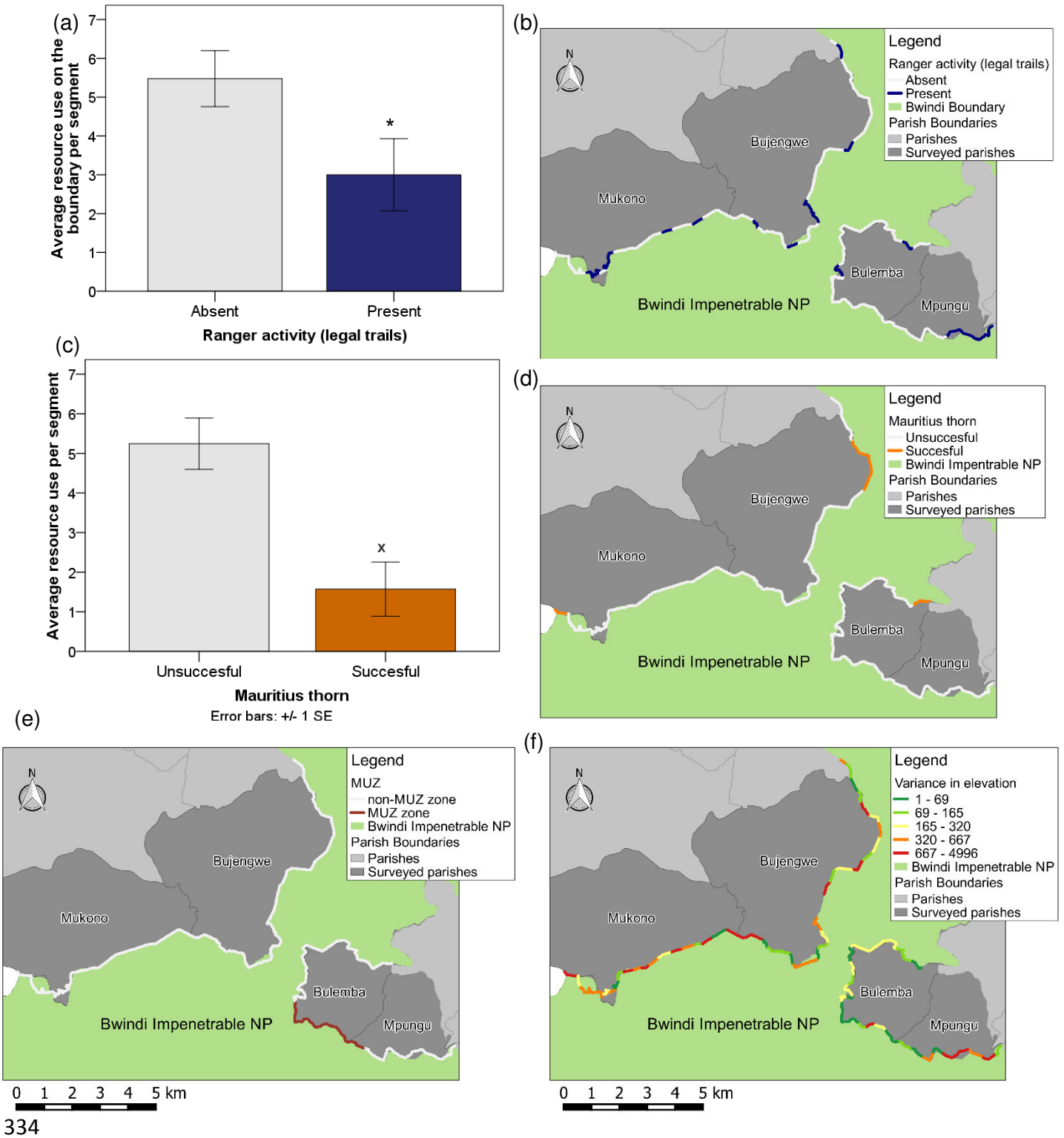
312

313 Harvesting of animals was only observed at an extremely low density in our forest surveys
314 but respondents mentioned it the second most frequently as a harvested resource. It was
315 the most commonly encountered resource in the 2016 ranger patrols and as they took place
316 further away from the boundary than our forest surveys, this is an indication that poaching
317 takes place deeper in the park. The other resources that the respondents said are
318 harvested from the forest (namely weaving materials, medicinal plants, honey, water and
319 edible plants) were only observed at a low density during the surveys and patrols. Pictures
320 of resource uses can be found in the Supporting Information.

321 **What factors influence human activity in BINP?**

322 ***Ranger activity***

323 Ranger activity, represented by the presence of legal trails on a given boundary segment,
324 had a significant negative effect on the number of instances of resource use on the
325 boundary (B= -0.723, p=0.022) (Figure 5a). We recorded ranger activity in a quarter of the
326 boundary segments (Figure 5b). Respondents mentioned ranger activity as a deterring
327 factor in a majority of the PMEs and KIIs and it was often residents' first response when
328 asked why they restrain from entering BINP. They mentioned they fear the presence of
329 rangers and getting killed, arrested or fined by rangers and mentioned anecdotes of
330 residents who got arrested and sent to prison to emphasise their point. One male Bakiga
331 resident in a leader position said: "There is a case of a person who one time was a poacher
332 and he went to the forest and he killed a yellow-backed duiker (…) and (…) was fined
333 heavily and from there people have feared the forest".



334

335 ***Figure 5*** *(a) Resource use on boundary vs ranger activity (p=0.022 (b) Map of segments*
336 *with ranger activity (c) Resource use on boundary vs Mauritius thorn (p=0.053) (d) Map of*
337 *segments with successful Mauritius thorn locations (e) Map of boundary segments with*
338 *MUZ (f) Map of variance of elevation per segment*

339 ***Mauritius thorn***

340 The presence of successful Mauritius thorn (higher than 1.5 meters) was associated with
341 lower resource use on the boundary (B=-1.084, *p*=0.053) (Figure 5c). Only 8.5% of the total
342 boundary we covered had successful Mauritius thorn (Figure 5d). Some mentioned the
343 benefits of Mauritius thorn, others complained about the poor management of the Mauritius
344 thorn project. One male Batwa resident said it "lacked manure and proper management"

345 ***Elevation***

346 Variance of elevation in a given segment (Figure 5f) did not have an effect on the amount
347 of activity in that segment. Terrain was also not directly mentioned as a deterring factor by
348 respondents although they mentioned that it is younger men who go into the forest as it is
349 physically challenging.

350 ***Multiple Use Zones (MUZ)***

351 The amount of resource use and illegal trails was not significantly different in the MUZ zone
352 (Figure 5g), also not after excluding the authorised resource uses within the MUZ
353 agreement (medicinal plants and basketry materials) from the total resource use on
354 boundary and on trails. A group comparison of the number of harvested medicinal plants
355 and basketry materials within and outside the MUZ also did not reveal differences in harvest
356 levels, neither on the boundary (Wilcoxon rank sum. W=289, *p*=0.0912), nor on trails
357 (Wilcoxon rank sum W=95, *p*=0.531). The MUZ users stated that the amount of resources
358 they were authorised to harvest under the agreement was insufficient to supply the local
359 population with medicine, and finished baskets and mats.
360

How can human activity in BINP be made more sustainable?

Solutions from residents

Residents often pointed to the problem of the lack of alternative resources as a reason for resorting to using resources from the park. Respondent residents were eager to establish more MUZs in collaboration with UWA. Another solution that was mentioned was that UWA provide seedlings of edible and medicinal plants from the park so that they can be domesticated and grown on village land. Finally, respondents would like to see an increase in their income so that they can afford buying finished products from an alternative source. In the residents' opinion, this money should come from either fundraising, the increased provision of employment or improved revenue sharing from tourist incomes. When asked what the barrier is to establishing these solutions, the answer residents gave related to UWA failing to receive requests or rejecting requests.

Solutions from UWA staff

Two UWA staff members pointed out the need to manage the risks from both legal and illegal use of BINP, saying that tourism and the associated developments need to be continually assessed for their sustainability. The remaining of the UWA staff put emphasis on solutions for illegal resource use. Opinions on increased law enforcement as a solution were divided, some advocated for it but others were of the opinion it would not necessarily be effective: "Patrols (…) to me it does not help, because people (…) know where patrols are (…). Let them know the value of this forest and alternatives. Some of these resources should be propagated outside in the farmlands. If a tree has medicinal importance, where can they put it in their [land]" A solution that had undivided support was raising awareness to help residents understand the connection between the conservation of BINP and the benefits that it brings. Some pointed toward the need of increasing these benefits, notably from tourism: either from the revenue sharing scheme that can be used to create projects like the domestication of wild resources and providing livestock, or the increase of individual benefits in terms of increased business and employment opportunities. One said: "If (…)

388 the park management can always consider people who are adjacent to the park, people
389 who could do (…) illegal activities, to consider them when they are recruiting rangers and
390 guides (…) [from] each parish which is connected with the park." Although some staff
391 members saw it as the task of UWA itself to upscale these benefits, others were of the
392 opinion that the residents were the limiting factor to the success of programmes meant to
393 increase benefits. One said "the communities their expectations, we have a program called
394 revenue sharing to address some of their needs but sometimes the expectations are
395 beyond, they look at this as total support for their livelihood". Another said "we are dealing
396 with people who do not understand even if when you help them propagate some of these
397 things (…) we give them seedlings, we give them even some initial capital, but (…) how
398 many come for it in the office? But you find that in the evening it is being illegally cut. (…)
399 The challenge is, so it's called ignorance."

DISCUSSION

Summarising the results, illegal resources that respondents reported to be taken from BINP are wood, bushmeat and fish, weaving materials, medicinal plants, honey, water and edible plants. Results from forest surveys indicated that resource use took place on the boundary (11 instances of resource use/km boundary) and on both legal and illegal trails (71 instances of resource use/km boundary) and the main spatial determinant of resource use was the presence of legal trails, which I assumed to be a proxy for ranger activity. Main solutions to making resource use more sustainable were more benefits in the opinion of residents and more awareness raising about existing benefits of the park in the opinion of UWA staff members.

Comparing the prevalence of resource use from respondent data and observational data, wood was the most common resources recorded during the forest surveys and poaching was most prevalent from patrol data, with firewood as the most common use of wood, consistent with previous studies (Olupot et al. 2009; Harrison et al. 2015). The observational methods did not allow for the consistent detection of other resource uses that respondents mentioned, most probably as they were hard to observe. A remarkable result is that grazing was not mentioned by respondents in our study nor in a previous respondent study ((Harrison et al. 2015) although it was recorded during ranger patrols and we observed signs of grazing during forest surveys including severe trampling along the boundary and trails in patches as well as a heard of livestock in the park. Although a previous forest survey conducted in 2001-2003 (Olupot et al. 2009, Olupot 2009, unpublished report) revealed signs of grazing, they were described as restricted with no evidence of heavy trampling and no instances of grazing were recorded in the North of Bujengwe, where we found the most significant patches of grazing.

From the four observable physical factors I hypothesised to have an effect on the levels of human activity, I only found one significant effect, namely the presence of legal trails (which

I used as a proxy for ranger activity) had a significant negative effect on resource use on the boundary. As I measured ranger activity through the presence of legal trails, I did not distinguish between the effect of patrols and the presence of rangers for other purposes. A possible interpretation of the effect could be that the mere presence of rangers, whether it is for law enforcement, tourism or research, deters residents from entering the park. This resonated with the respondent data as residents seemed to fear the general presence of rangers in the park rather than just patrols. Therefore, investing in tourism, which is an income generating activity, might be more beneficial than carrying out more patrols.

Mauritius thorn had a negative relationship to resource use on the boundary as well, although only close to significance (p=0.053). One explanation for this could be that Mauritius thorn deters people by acting as a thorny barrier. Another explanation could be that successful Mauritius thorn, as intended, prevents animals from coming out of the park to raid crops. This in turn could then prevent loss of income from crop losses and/or improve residents' attitudes towards the park, reducing their tendency to resort to illegal activities. Respondents did indicate that Mauritius thorn could be a useful tool to deter crop raiding animals but that it lacked management and manure. Mauritius thorn intervention was indeed only successful on 8.5% of the boundary we surveyed. As this study gives a first indication on the potential of Mauritius thorn to reduce illegal activity, further investigation of its effects and how it can be better managed would be useful.

Variance of elevation and the presence of an MUZ did not have an effect on human activity. We measured the variance of elevation in each segment as a proxy for steepness of terrain, but measuring the percentage of sloping might be a more accurate measure. MUZs did not show reduced levels of harvesting of the authorised resources (basketry materials and medicinal plants) nor of the other, illegal activities. This could be explained by the fact that the MUZ programme is only active for a few days per year, meaning illegal resource use could still take place for the rest of the year. Respondent data might give an indication as

to why this is happening, as some mentioned that the few days of authorised resource collection per year under the MUZ programme was inadequate in providing the local population with sufficient resources. Increasing the amount of MUZ zones could be a solution to this. It was also put forward as a solution by both UWA and resident respondents along with domesticating resources from BINP.

For the other solutions proposed by respondents there was a discrepancy between UWA staff, who were putting more emphasis on community awareness, and the residents themselves, who wanted to see more benefits. The main limiting factor for the implementation of solutions seemed to be the reluctance of UWA to accept requests from the resident perspective, but some UWA wardens were of the opinion that residents were unwilling to cooperate. It therefore seems essential for managing bodies like UWA and their NGO partners to improve communication and tailor interventions better to the residents to avoid a mismatch in expectations.

The main recommendations are:

1. Address the issue of grazing, which seems to be on the rise and is currently not mentioned in the management plan
2. Further research the potential effects of ranger activity and Mauritius thorn to reduce illegal activities
3. Increase the amount of MUZ zones and support the domestication of resources from BINP to reduce residents' dependence on resources from BINP
4. Tailor future interventions better to the demand of residents to increase cost-effectiveness and resident satisfaction

ACKNOWLEDGMENTS

I thank my supervisors at Imperial College London (ICL), Dr. Marcus Rowcliffe, at Oxford University, Dr. E.J. Milner-Gulland and Dr. Henry Travers, and at the NGO Conservation through Public Health (CTPH), Dr. Gladys Kalema-Zikusoka. I thank CTPH for hosting me. I thank the Uganda Wildlife Authority for giving permission and support for data collection. I thank ICL and The Darwin Initiative for their financial support.

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SUPPORTING INFORMATION

Appendix S1: Overview of respondent data collection: participatory mapping exercises (PMEs) and key informant interviews (KIIs)

For PMEs and KIIs with residents, I selected a random village in each of the four parishes in the research area. My field assistant then contacted the chairman of each village a few days in advance. The chairman was asked to assemble a group of 7 men, 7 women and 7 stretcher group members (4 men, 3 women or 3 men, 4 women). We asked the chairman to have a mix of ages and socio-economic backgrounds in each group and not to include people who had leader positions in the village to avoid dominant speakers and to allow participants to speak freely. We also asked the chairman if we could speak to him and to ask a stretcher group chairman (different than the stretcher group for the PME) and a HUGO chairman (in villages with HUGOs) if we could speak to them. In Mpungu there were Multiple Use Zone users in the village so we asked for a group of women and men who were MUZ users and a group of women and men who were not.

For the Batwa, the procedure was similar, except we only asked to speak to a group of women, a group of men and the leader him or herself as there are no Batwa stretcher groups.

Participatory mapping exercises took around 1 hour and 30 minutes and we gave each participant a token of appreciation in the form of a bar of blue soap and 500 gram packet of salt. Key informant interviews with residents took around 30 minutes and we gave them a token of appreciation in the form of a bar of soap, except the chairman/leader, who we gave small fee as a thank you for organising the PMEs and KIIs.

An overview of all the PMEs and KIIs can be found in the table below.

Parish	PMEs	KIIs
Residents Mukono	7 Bakiga men 7 Bakiga women 7 Bakiga stretcher group 7 Batwa women 7 Batwa men	Village chairman Stretcher group chairman HUGO chairman Batwa leader
Residents Bujengwe	7 Bakiga men 7 Bakiga women 7 Bakiga stretcher group 7 Batwa women 7 Batwa men	Village chairman Stretcher group chairman HUGO chairman Batwa leader
Residents Mpungu	7 Bakiga non-MUZ user men 7 Bakiga non-MUZ user women 7 Bakiga MUZ user men 7 Bakiga MUZ user women 7 Bakiga stretcher group 7 Batwa women 7 Batwa men	Village vice-chairman Stretcher group chairman Batwa leader
Residents Bulemba	7 Bakiga men 7 Bakiga women 7 Bakiga stretcher group	Village chairman Stretcher group chairman
UWA staff	-	Chief Warden Warden of Monitoring and Research Warden of Tourism Warden of Community Conservation Assistant Head Ranger Guide Law enforcement ranger Former ranger
Total	20	20

Appendix S2: Positionality statement

I am a 25 year-old woman born from a Dutch father and a Hungarian mother and I grew up in The Netherlands, Hungary and Belgium. I was raised in a middle-class conservative family with loosely Christian views but consider myself agnostic. I have completed research with rangers in 2013 in rural Tanzania, in a context similar to this research. This could have influenced my positionality and to avoid this I exercised cultural reflexivity during the data collection and analysis process and I chose for an inductive coding process to avoid imposing my pre-constructed concepts and views on the interview and focus group data.

I positioned myself as an outsider and informed the respondents about the fact that I am a researcher. As a foreign researcher coming into the field, I might have obtained information from the respondents that they deemed appropriate for the context of my position or my research. To mitigate this, I employed a translator who was born and raised in the research area and knew the language and cultural norms in the study area. This in turn could have led to a bias as my translator knew some of the participants but not others, meaning some respondents might have been more or less open as they knew the person interviewing them. I therefore ensured that I would not extrapolate the views of an individual to a whole group in my analysis and write-up, choose quotes that are representative of the larger study population and/or specify the proportion or number of respondents who mentioned a certain theme.

Lastly, the translation itself is another source of bias in the research. I led interviews and focus groups in English and asked the translator to translate the respondents' and my statement after each sentence. Before the start of the research, I had a training session with my translator where we went through the guides and he translated them while asking questions about certain words, expressions and concepts. I informed my translator that the translation of the guides should be consistent throughout the research. We practiced the translation and protocol of the participatory mapping and the translation of the key informant interviews. We piloted two focus groups and one key informant interview with residents in a village outside the study area. After the pilot, my translator and I went through the recording to correct for ambiguities arising from imprecise formulations of questions and improved the general flow of the key informant interviews and participatory mapping exercises. After the research period I went through the recordings with my translator to fill gaps in translation.

Appendix S3: Ethical review process

Ethical approval was obtained from Imperial College prior to the collection of data by providing information on environmental issues, animal/plant handling issues, human subject issues and institutional issues. The Conservation Science course directors (Imperial, ZSL, Kew, Durrell) approved the proposals, using the above-mentioned internal ethics approval form.

I obtained a research permit from the Uganda Wildlife Authority prior to the research, which authorised me to carry out research with participants and perform forest surveys. I was accompanied by two UWA rangers at all times during the forest surveys, in compliance with UWA regulation.

Before conducting interviews and participatory mapping, participants were given a brief outline of the study and its aims and were asked if they consented to the use of their data by signing their name on a consent form. I have the written records of the consent of all the participants. All were given the option to withdraw their information or not take part in the study if they felt uncomfortable in any way (see guides below).

Appendix S4: Guide for participatory mapping exercise (PME) (established with the help of V. Griffiths, unpublished data)

Materials:

- camera
- recorder
- markers, colour markers, flipchart paper
- beans, peas etc.
- tokens of appreciation

Introductions

Thank you all for coming, my name is Fran Olsthoorn and this is Christopher Byaruhanga. I am an independent research student at Imperial College in England.

Goal of the exercise

We want to learn more about the way of life and opinions of people living here. The aims of this group discussion are to find out two things:

- What natural resources are the most important for people in this area
- What are the challenges in getting resources for people's livelihoods

I would like to invite you to create a map of the area together and participate in a group discussion. It should only take about two hours of your time and it is anonymous.

Assurance of confidentiality

Thank you for agreeing to meet with us. We hope that you will be able to provide us with some of your own ideas and experiences. We realise that the resources you use will be different from person to person and that you may not want to share some of the more private and personal things with other people, including us or other people in this group. This is completely fine, and we will not ask you to say anything that could make you uncomfortable. What is said during this meeting is private so please do not share the information with anyone else. We will make sure that your answers are kept anonymous and we will not share them with other members of the community, the local authorities or any other authorities. We want to invite each and every one of you to speak up individually as we are interested in your individual opinions. People will have different opinions so it is important that we all respect each other's opinions and give everyone a chance to speak.

Voluntary participation

As this exercise is voluntary, you may stop the discussion at any time. If you have any questions, please ask us.

If you have a concern about any aspect of this project, please speak to me and I will do my best to answer your query.

We would also like to use some direct quotes from you and they will be anonymous.

Obtaining consent

Do you have any questions or concerns so far? [Pause here to give people enough time to think and comment]

Would you like to continue with the meeting? [Form signing]

Obtaining permission to record and take pictures

Would you mind if we take photos and audio record this meeting so that we can make sure that we don't miss anything important that you tell us?

[Get verbal consent; if anyone objects to being recorded or photographed, do not record the meeting]

[turn on recorder if no one objects]

As Christopher is translating live, we want to make sure we don't miss anything that is lost in translation. Can you therefore make sure you speak in Rukiga so everyone in the group understands and please stop after every statement so that Christopher can translate?

Directions for doing the ground mapping

We are interested in getting to know more about what natural resources are important to your livelihoods. We would like to make a map with you

- Villages: that we will draw on a big piece of paper and with the help of the materials you have received
- Batwa: that we will draw on the ground and complement with the materials you have received

- Let's first map the village

[ask specific people for each element, make legend in English (Fran) and Rukiga (Chris)]

  - the main road
  - what other roads are there?
  - is there a school?
  - is there a church?
  - is there a trading centre?
  - Is there a health centre?
  - where are the water ways?
  - Which food crops do you grow?
  - Which cash crops do you grow?
  - So now we have drawn food crops and cash crops, what about wild natural resources, what wild natural resources exist in the area?

[maize – honey

g-nuts – meat

raisins – berries

pencils – timber

beans – basketry materials

soybeans – medicinal plants]

Now we have a list of these resources, let's see one by one why they are important for people around here.

  - What is x used for in the village?
    [probes: construction, cooking, eating, feeding, weaving, selling etc.}

  - In some area of Bwindi there are multiple resource agreement for some resources. Is there a multiple resource agreement here for x?
    [probes: look for a long time/short time, scarce, abundant, easy to find, hard to find]

First round: You can now each take your different grains. Let's start with x, which we will represent with y.

Next rounds: we will represent x with y.

- Can x be found in the village?
  First ask one person to put it on the map, then the rest]

- Is there x elsewhere?
  First ask one person to put it on the map, then the rest]

- Is there enough of x for everyone? Do people struggle to get x? How do you make sure everyone gets enough x?
  [lack of the resource,]

- Now that you said, there is a challenge as there is not enough x for everyone, what do you think some people might do to provide enough for their livelihoods? What about those/you who do not have a permit to access resources?
  [probes: near forest edge, buy from people who go into forest, go into forest, buy from other villages]

Now we have a complete map of the resources, have we forgotten anything? Does anyone want to add?

Do you know if anyone has gotten called out for getting some resources in the forest? From this community or another?

[UWA, reporting, LC1 chairman]

Is there anything anyone would like to add?

Closure

Thank you very much for your time, we really appreciate it. This has really helped us understand what natural resources are important to you and has helped the research. If you have any concerns, please call me on 0770844898. [give token of appreciation]

Appendix S5: Guide for key informant interviews (KIIs) (established with the help of V. Griffiths, unpublished data)

Materials:
Recorder
Notebook

Introductions

Thank you for meeting us, my name is Fran Olsthoorn and this is Christopher Byaruhanga. I am an independent research student at Imperial College in England.

Goal of the interview

I would like to ask you some questions about how you think people depend on natural resources.

Assurance of confidentiality

What is said during this interview is private. Your answers will be kept anonymous and will only be used for research purposes.

Voluntary participation

The interview is voluntary and you can stop anytime or come back on things you have said. Please let me know if you have questions.

Obtaining consent

Is this ok?
Do you have any questions or concerns so far? [form]

Obtaining permission to record

Would you mind if we record this interview so that we can make sure that we don't miss anything important that you tell us?

Questions village chair

What village are you the chair of?

What is your role in the village as a chair?

How long have you been chair of this village?

What are the main challenges you face in the village as an LC1 chairman?

So we are interested as we said in how different natural resources people depend on in this area, so we will ask you some questions about that.

What crops do people grow in the village?

Are people dependent on any other resources?

Is there a multiple resource agreement for some resources?

What are then the challenges in getting enough of these resources?

Do people express their concerns to you about the lack of these resources?

As people struggle to get by from the available resources, do you find some people are forced to get these resources from the forest?

Do some people buy some wild natural resources in markets?

Have you had cases where some people were reported to go into the forest?

Have you had to report people personally?

Does UWA patrol around here? Have people been unfortunate enough to be caught?

What do you think would improve the situation to deal with the lack of resources?
CTPH parishes: In your opinion, does CTPH's work contribute to reduce the amount of times people go into the forest to get natural resources? In which ways?

Questions stretcher group chair

How many stretcher groups are there in the village?

What stretcher group are you the chair of?

What is your role in the village as a stretcher group?

How long have you been chair of the stretcher group?

What are, in your opinion, the main challenges in the village?

So we are interested as we said in how different natural resources people depend on in this area, so we will ask you some questions about that.

What crops do people grow in the village?

Are people dependent on any other resources?

Is there a multiple resource agreement for some resources?

What are then the challenges in getting enough of these resources?

Do people express their concerns to you about the lack of these resources?

As people struggle to get by from the available resources, do you find some people are forced to get these resources from the forest?

Do some people buy some wild natural resources in markets?

Have you had cases where some people were reported to go into the forest?

Have you had to report people personally?

Does UWA patrol around here? Have people been unfortunate enough to be caught?

What do you think would improve the situation to deal with the lack of resources?

Questions HUGO chair

How big is the HUGO team in this village?

How long have you been chair of the HUGO group?

What are the responsibilities of the HUGO group?

What are, in your opinion, the main challenges in the village?

So we are interested as we said in how different natural resources people depend on in this area, so we will ask you some questions about that.

What crops do people grow in the village?

How often are you called out? What do HUGOs do when they are called?

Do people always call HUGOs when gorillas or other animals are raiding crops?

Do people only rely on crops or also some wild natural resources?

What are then the challenges in getting enough of these resources?

Do people express their concerns to you about the lack of these resources?

As people struggle to get by from the available resources, do you find some people are forced to get these resources from the forest?

Have you heard of cases where people went into the forest and encountered gorillas there?

Does UWA patrol around here? Have people been unfortunate enough to be caught?

What do you think would improve the situation to deal with the lack of resources?

Questions UWA staff/rangers

What is your role within UWA?

How long have you been in this position?

What are your responsibilities in this position?

What are, in your opinion, the main challenges around Bwindi at the moment?

So we are interested as we said in how different natural resources people depend on in this area, so we will ask you some questions about that.

Do you think people only rely on crops or also some wild natural resources?

Do you find some people are forced to get these resources from the forest?

How do you prevent people from going into the forest?

How often are there patrols in Bulemba, Mpungu, Mukono, Bujengwe?

Is the effort uniform over Bwindi?

What is the frequency of arrests in each of these parishes?

What is the most common human activity in the forest?

What is the sanction?

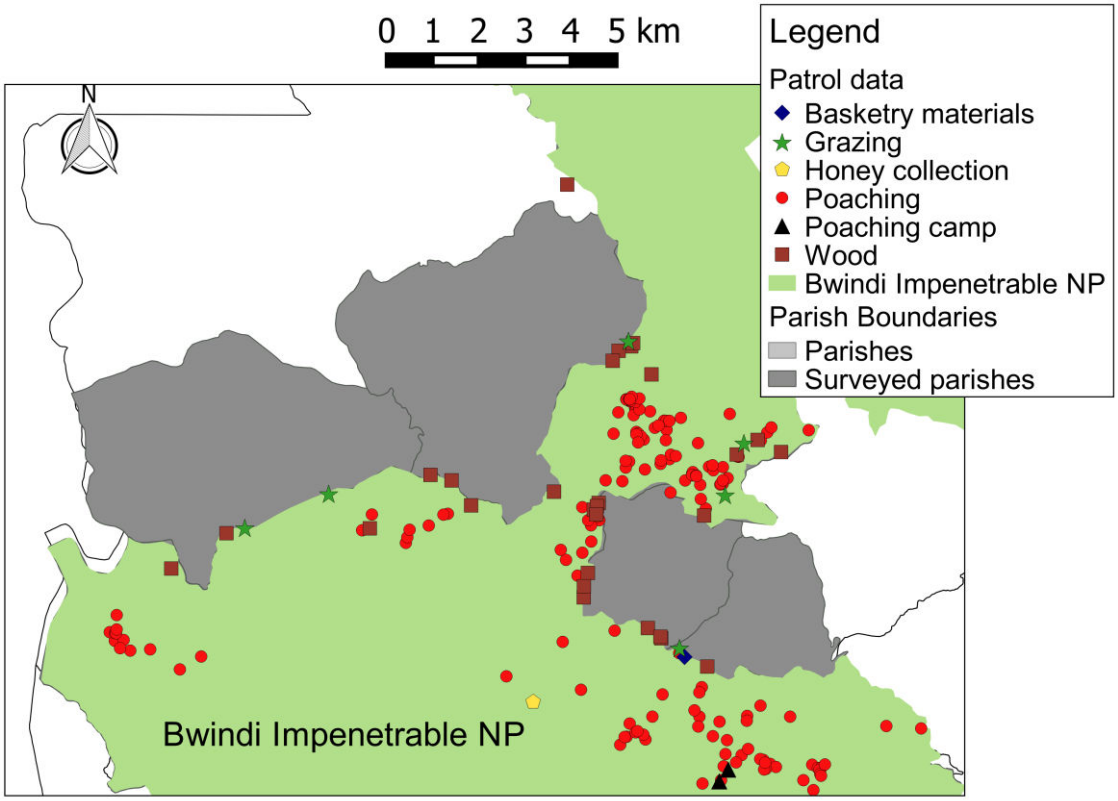
Why do you think people go into the forest to get natural resources?

What do you think would improve the situation to have less people go into the forest?

Appendix S6: Different species of resources mentioned by respondents

Category	Use	Common name in English	Scientific name
Wood	Firewood and charcoal burning	-	*Agauria salicifolia*
Wood	Timber	Sapele	*Entandrophragma cylindricum*
Wood	Timber	East african satin wood	*Zanthoxylum gillettii*
Wood	Timber	Umbrella tree	*Maesopsis eminii*
Animal protein	Bushmeat	Yellow-backed duiker	*Cephalophus silvicultor*
Animal protein	Bushmeat	Black-backed duiker	*Cephalophus nigrifrons*
Animal protein	Bushmeat	Giant forest hog	*Hylochoerus Meinertzhageni*
Animal protein	Bushmeat	Bushpig	*Potamochoerus larvatus*
Animal protein	Bushmeat	Monkey species	-
Animal protein	Bushmeat	Mongoose species	-
Animal protein	Bushmeat	Guinea fowl species	-
Animal protein	Bushmeat	Francolin	-
Animal protein	Fish	Mudfish	-
Animal protein	Fish	Lungfish	-
Weaving material	Small baskets for eating and handcrafts	-	*Setaria sp.*
Weaving material	Baskets for plucking tea	-	*Losiniera apocynoides*
Weaving material	Trays and baskets for carrying food	-	*Smilax anceps*
Medicinal plant	Medicine	-	*Rytiginia kigeziensis*
Medicinal plant	Medicine		*Gouania longispicata*
Medicinal plant	Medicine	-	*Piper guineense*
Medicinal plant	Medicine	Lucky bean tree	*Erytherina abyssinica*
Medicinal plant	Medicine	Bitter leaf	*Vernonia amygdalina*
Medicinal plant	Medicine	Red vine spinach	*Basella alba*
Medicinal plant	Medicine	-	*Ocotea sp.*
Medicinal plant	Chases away spirits	-	*Myrica salicifolia*
Edible plant	Staple food	Yam species	*Discorea sp.*
Edible plant	Vegetable	Wild eggplants	*Solanum sp.*
Edible plant	Fruit	-	*Myrianthus holstii*
Edible plant	Fruit	-	*Impatiens sp.*
Edible plant	Fruit	-	*Aframomum melegueta*

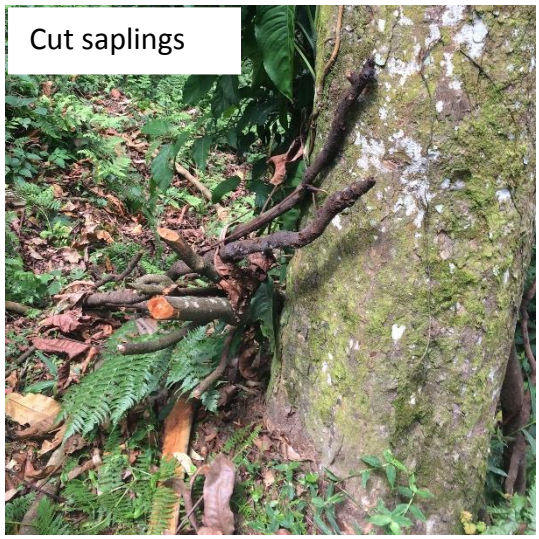
Appendix S7: map of compiled patrol data of 2016. Patrols took place at varying levels of efforts in various locations throughout the year.



Appendix S8: Pictures of instances of resource uses

Cut firewood

Cut saplings



Cut pole

Cut beer boat

Snare

Medicinal plant collection -

Honey

Water

Grazing (1)

Grazing (2)

Appendix S9: Regression models for resource use on the boundary, number of illegal trails and resource use on trails (results of negative binomial regression)

Resource use on the boundary				
	B(SE)	95% CI for odds ratio		
		Lower	Odds ratio	Upper
Constant	-4.518 (0.186)	0.008	0.011	0.016
Elevation	0.000 (0.000)	1.000	1.000	1.000
Mauritius thorn	-1.084[x] (0.560)	0.117	0.338	1.105
Ranger activity	-0.723* (0.313)	0.264	0.485	0.916
MUZ	-0.002 (0.4000)	0.474	1.002	2.315
R^2=0.347 (Hosmer-Lemeshow) Model X^2=33.333, p<0.001 *p<0.022, [x]p<0.053				

Number of illegal trails				
	B(SE)	95% CI for odds ratio		
		Lower	Odds ratio	Upper
Constant	-4.625 (0.407)	0.007	0.010	0.014
Elevation	0.000 (0.000)	1.000	1.000	1.000
Mauritius thorn	-0.017 (0.461)	0.422	0.983	2.629
Ranger activity	-0.220 (0.279)	0.469	0.802	1.404
MUZ	-0.037 (0.366)	0.520	1.037	2.204
R^2=0.497 (Hosmer-Lemeshow) Model X^2=41.887, p<0.001				

Resource use on trails				
	B(SE)	95% CI for odds ratio		
		Lower	Odds ratio	Upper
Constant	-3.653 (0.272)	0.015	0.0259	0.045
Elevation	0.001 (0.000)	0.999	1.000	1.002
Mauritius thorn	-0.511 (0.706)	0.179	0.600	3.060
Ranger activity	-0.539 (0.487)	0.2223	0.583	1.663
MUZ	-1.042 (0.585)	0.122	0.353	1.249
R^2=0.547 (Hosmer-Lemeshow) Model X^2=27.409, p<0.001				