# Evaluating the prospects of benefit sharing schemes in protecting mountain gorillas in Central Africa

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# Evaluating the Prospects of Benefit Sharing Schemes in Protecting Mountain Gorillas in Central Africa*

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**Abstract**

Presently, the mountain gorilla in Rwanda, Uganda and the Democratic Republic of Congo is endangered mainly by poaching and habitat loss. This paper sets out to investigate the possible resolution of poaching involving the local community by using benefit sharing schemes with local communities. Using a bioeconomic model, the paper demonstrates that the current revenue sharing scheme yields suboptimal conservation outcomes. It is however shown that a performance-linked benefit sharing scheme in which the Park Agency makes payment to the local community based on the growth of the gorilla stock can achieve socially optimal conservation. This scheme renders poaching effort by the local community, and therefore poaching fines and anti-poaching enforcement towards the local community unnecessary. Given the huge financial outlay requirements for the ideal benefit sharing scheme, the Park Agencies in central Africa could reap more financial benefits for use in conservation if they employ an oligopolistic pricing strategy for gorilla tourism.

**Keywords:** Benefit sharing, bioeconomic model, conservation, mountain gorilla, performance payment

## 1 Introduction

The need for biodiversity conservation has long been recognized, though it was only formalised with the signing of the Convention of Biological Diversity in

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1992. In Africa, prominence has been given to the conservation of large individual species, such as the elephant, black rhino and the gorilla. In Rwanda, Uganda and the Democratic Republic of Congo (DRC), the gorilla is a key species faced with a range of threats: poaching, war, growing human populations and associated habitat loss, and natural epidemics. The gorilla is presently endangered, and appears in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Conservation efforts around the gorilla include the International Gorilla Conservation Programme (IGCP), the Great Ape Survival Project and the Agreement on the Conservation of Gorillas and Their Habitats (Convention on Migratory Species [2008]). Thus, it is clear that global society values endangered species such as the gorilla. However, in the countries in which such species still exist there seem to be inadequate incentives to enable the conservation of the optimal populations.

There are two species of gorillas, namely the Western and the Eastern, each with two subspecies. The two subspecies of the Eastern gorilla are the Mountain and the Eastern Lowland Gorilla (UNEP – WCMC [2003]). The Mountain Gorilla (*Gorilla beringei beringei*) is the most endangered, with a total population of 786 individuals (IGCP [2010a]) and is therefore the focus of this paper. The relevant gorilla range in Rwanda, Uganda and the DRC occurs in an area called the Virunga Massif. The annual revenue earned directly from gorilla tourism in these countries is currently estimated to be US$3 million, before the employment opportunities created are even considered (ICGP [2011]). Accounting for first-order multiplier effects, gorilla tourism contributes over US$20 million annually, apportioned between Rwanda, Uganda and the DRC (ICGP [2011]).

However, even though these countries earn a lot of revenue from gorilla tourism, this revenue does not trickle down to the communities who shoulder the opportunity cost of land not used in agriculture and suffer from crop damage. Given that in many cases national parks were created by directly displacing rural communities, benefit sharing helps reduce the sense of grievance that local communities feel towards their creation (Adams and Infield [2003], Schulz and Skonhoft [1996]). Consequently, benefit sharing must assume prominence, given the role of human interaction (via poaching, encroachment through agriculture or settlement, etc.) on possible extinction.

The current incentive scheme in the Virunga Massif entails sharing revenue from gorilla tourism with the local community. This is used to finance community projects for enhancing community welfare. The exact proportions shared differ for each of the three countries but range between 5% and 30%. Certainly the flow of revenue has helped win some compliance from local communities, even though local attitudes towards wildlife are still fairly negative (Adams and Infield [2003]). The current conservation outcomes could therefore be improved by changing the design of the incentive scheme.

The role of benefit sharing schemes has been discussed in similar contexts by Schulz and Skonhoft [1996], Skonhoft and Solstad [1996], Skonhoft [1998], Fischer et al. [2011] and Zabel et al. [2011]. Like Schulz and Skonhoft [1996], we argue against merely compensating local communities for wildlife damages and call for benefit sharing schemes which attract local communities to undertake actions to allow the wildlife populations to grow. Poaching by local communities can be addressed more effectively by granting them property rights to wildlife because without them local communities base their illegal harvesting decisions on short-term considerations (Skonhoft and Solstad [1996]).

In a model with a land-use conflict between local agropastoralists and a park authority, Skonhoft [1998] introduces property rights by allowing the agropastoralists to share the profits from wildlife hunting and tourism. Where the agropastoralists receive a profit share from the tourist activity above that of the hunting benefit, the nuisance from the roaming wildlife will decrease as this scheme gives incentives for the park manager to increase the offtake and thereby decrease the wildlife stock in the long term. There will therefore be more livestock and a clear welfare gain for the agropastoralists compared to the situation where they have no property rights. Under certain conditions, the stock sizes will also be closer to what is optimal from an overall point of view. Consequently, Skonhoft [1998] supports devolution of ownership rights to the local agropastoralists to incentivise them to develop a long-term view about wildlife conservation.

Using a similar property rights structure, Fischer et al. [2011] shed more light on the welfare implications of such schemes by comparing two benefit sharing schemes involving sharing tourism revenue and shares of hunting licenses in a bioeconomic model incorporating poaching by external agents and community anti-poaching enforcement. It turns out the size of benefits granted and the design of benefit sharing schemes is crucial if resource sharing is to translate into meaningful conservation and welfare improvements. Fischer et al. [2011] argue that directly linking benefits to the actions of locals can result in significant conservation outcomes.

Zabel et al. [2011] evaluate two policy approaches for carnivore conservation: ex-post compensation, and performance payments. While both of the policies they evaluate have the capacity to enhance conservation outcomes, unconditional ex-post compensation is shown to have a distortionary effect on incentives to conserve. They argue that performance payments are more effective because of their direct link to specific conservation outcomes. Accordingly, this paper will propose a scheme which is more in line with Zabel et al. [2011]'s performance payment scheme with the difference that in our case the primary motivation is not to compensate for damage inflicted on the local community but generally grow the gorilla population. In addition, we will argue that it is the generation of adequate financial incentives which encourages communities to have a long-term view in their interaction with wildlife besides the mere designation of communities as co-owners of wildlife.

Against the background that the gorilla has remained threatened, despite decades of research and many efforts to save it, this paper seeks to investigate the possible resolution of part of the poaching problem using benefit sharing schemes with local communities. Using a bioeconomic model, the paper investigates the conservation and welfare outcomes in the Virunga Massif of the revenue sharing scheme in place and the proposed performance-linked benefit sharing scheme in which the Park Agency makes payment to the local community based on the growth of the gorilla stock. The paper is organized as follows: section 2 gives a detailed background of the mountain gorillas' ecology, the key threats and current conservation efforts found in the Virunga Massif. Section 3 outlines the bioeconomic model. Section 4 discusses the market equilibrium. Section 5 presents the social planner's solution, compares it with the market equilibrium, and discusses the current and alternative benefit-sharing schemes while section 6 concludes the paper.

## 2 Background to the Problem

The mountain gorilla exists naturally in two small, isolated populations, found in two locations which form their last remaining natural habitat. The Virunga Massif - situated on the slopes of extinct volcanoes along the borders of the DRC (the Mikeno sector of the Virunga National Park, 7900km$^2$), Rwanda (Volcanoes National Park, 160km$^2$) and Uganda (Mgahinga Gorilla National Park, 33.7km$^2$) - is home to about two-thirds of the total gorilla population. The other population is found in Bwindi Impenetrable National Park (BINP) in south-west Uganda, on the border with the DRC (331km$^2$) (UNEP – WCMC [2003], UNEP [Undated]).[1] The mountain gorillas of the Virunga occupy an area of approximately 450km$^2$, while the Bwindi gorillas occupy about 215km$^2$ (UNEP – WCMC [2003]). The Virunga population was estimated to be 480 in 2010; the Bwindi population totalled 302 according to the 2006 census (ICPG [2010a], Nellemann, Redmond and Refisch [2010]). The mountain gorillas' home range in the Virunga is small, between 5 and 30km$^2$; therefore, daily foraging movements may involve crossing national borders. The Bwindi population is relatively stable and even increasing, according to the 2006 census (McNeilage et al. [2006]). Moreover, the Bwindi gorillas have not been disturbed by humans as much as the Virunga population has (Robbins et al. [2009]). The distribution of the mountain gorillas is shown in figure 1.

At present, all mountain gorillas and their respective habitats are found in 'protected' areas. However, such protection is undermined by political and institutional instability, and by illegal hunting.[2] Recent concerns are poaching for the bushmeat trade and for the capture of infant gorillas, and the impact of civil conflict within the gorillas' range (UNEP [Undated], Plumptre and Williamson [2001], IUCN [2010], Kalpers et al. [2003]).

[1] The Virunga National Park was designated a World Heritage Site in 1979 and a World Heritage Site in Danger in 1994; while the Volcanoes National Park was created in 1929 and designated a Biosphere Reserve. The Bwindi Impenetrable National Park is also a World Heritage Site in Danger (Lanjouw et al. [2004]).

[2] Historically, the mountain gorilla has been at risk of extinction from various pressures at different times and in different areas. Threats have encompassed poaching, loss of habitat due to agricultural expansion, illegal cattle grazing, growing human population, destruction and fragmentation of habitat due to logging, mining and charcoal production, climate change, war, and natural epidemics (e.g. Ebola) and the risk of diseases passed from humans to gorillas (a threat to habituated gorillas in areas of gorilla tourism) (Plumptre and Williamson [2001], IUCN [2010], Robbins et al. [2009]).

Despite the recent recovery of the population, current threats of extinction are as real as they were in the 1950s. The current mountain gorilla population is less than the theoretical minimum for survival, meaning they are more vulnerable to stochastic catastrophic events such as outbreaks of disease and sudden loss of habitat (UNEP [Undated]).

While previous studies on the mountain gorilla in the Virunga region have indicated population viability for the next 100 years in the absence of external environmental perturbations (Harcourt [1995], Miller et al. [1998], Durant [2000] cited in Kalpers et al. [2003]), conservative projections by UNEP in 2002 forecasted that the mountain gorillas' natural habitat will have shrunk to only 10% of its original range by 2032. Moreover, there are social consequences - often associated with the killing of a key member of a group, for example a silverback. This could cause the disintegration of an entire group; and infanticides, as nursing mothers join a new male, thereby triggering population regression (UNEP [Undated], Kalpers et al. [2003]). This clearly shows the impact of increasing human interaction with natural processes in the absence of drastic action to halt this trend (Nellemann et al. [2010]).

**Gorilla Poaching**

The threat of poaching is a challenge to gorilla conservation. Binyeri, Hibukabake and Kiyengo [2002] have documented instances of gorilla poaching driven by the increasing demand for baby gorillas from private foreign zoos in the DRC. Williamson and Fawcett [2008] have reported similar incidents for Rwanda. An infant can yield up to £86 000 on the black market (Vesperini [2002] cited in UNEP - WCMC [2003]). And in most cases infants can only be captured after killing the adults in the group who are meant to protect them (UNEP – WCMC [2003]).

The Virunga region remains largely politically unstable, further increasing threats to gorillas (Kalpers et al. [2003], IUCN [2010]). Bringing an end to the activities of the militia through halting the profits from illegal activities could stop the destruction of rain forests and mountain gorillas. In addition, isolation and low population numbers raise concerns about inbreeding (Kalpers et al. [2003], UNEP – WCMC [2003]).

**Habitat loss**

The Virunga region is under considerable pressure from competing land-uses, most notably agriculture. Subsistence agriculture is the primary livelihood strategy for communities located around the parks (>90% of the population) (Plumptre and Williamson [2001]). The land surrounding the Virunga Massif is highly fertile because of volcanic deposits and is generally considered conducive to agriculture. Consequently, high human population densities (between 400 and 600 people per $km^2$) are a common feature (Plumptre and Williamson [2001], Kalpers et al. [2003]). In addition, the national parks do not have buffer zones between the local communities and the parks' resource base. A proposal in 2000 to resettle refugees in the Volcano National Park, and the subsequent deforestation (in 2004) of $15km^2$ in just one week for conversion to farmland in the Mikeno sector (NASA [2005]) as well as the sharp increase in timber extraction for the illegal production of charcoal clearly demonstrate the extent of the threat of habitat loss for gorillas. Periodical refugees have set up temporary structures in the Virunga National Park, putting further pressure on the habitat. The Virunga Massif is of enormous conservation importance as it encompasses areas of high irreplaceability and high vulnerability (Stage et al. [2005]). The current gorilla habitat and range is considered to be only a fraction of what it used to be; losing more habitat, therefore, will greatly endanger the survival of the remaining gorilla population (Plumptre and Williamson [2001]).

The recent recovery of the mountain gorilla populations indicates the potential of trans-boundary collaboration, and highlights the fact that given adequate resources, these gains could be reinforced by an appropriately designed incentive scheme. Protected areas, regional collaboration and community involvement currently offer the main formal tools that (in theory) will protect the mountain gorillas and preserve biodiversity in the Virunga region (Nellemann et al. [2010], Skonhoft [2005]). This is crucial, since the probability of extinction of a species depends fundamentally on the quantity and quality of their ecological habitat.

Recently there has been increased emphasis on community involvement and regional collaboration. Community initiatives have included revenue sharing schemes and provided alternative livelihoods which do not threaten wildlife. These arise from the recognition that when traditional rights and access shift in a way which disadvantages local communities, little incentive is created to exploit resources in a sustainable manner (Damania et al. [2003], Johannesen and Skonhoft [2005]). However, lack of institutional capacity is proving an obstacle (Adams and Infield [2003]). In addition, given the insignificant magnitude of the benefits per person from revenue sharing - about US$0.36 per year in Rwanda (Nielsen and Spenceley [2010]) - there is a need for careful design of the scheme so that it has a more pronounced first-order impact on the local community.

**Gorilla Tourism**

Increasing pressure on the land has been the driving force behind gorilla tourism, in the hope that if gorillas can 'pay their way', then this could increase the opportunity cost of their natural habitat. Where gorilla tourism has developed, mountain gorillas have become an economic asset of national importance. Gorilla tourism dates back to 1979 and 1984 in Rwanda and the DRC respectively, while official gorilla tourism in Uganda was established in 1991. The strong demand for gorilla tracking offers the possibility for sustained wealth generation from wildlife. To consolidate the benefits of tourism, institutions need to be devised such that the gorilla 'pays its way' to the satisfaction of all parties (Adams and Infield [2003]). However, gorilla tourism is not without challenges; it exposes gorillas to humans and hence to any diseases that humans may be carrying, thereby greatly exposing immunologically naïve populations (Plumptre and Williamson [2001]).[3] In addition to possible stress during the habituation process,[4] habituation increases risks to the gorillas from poachers

[3] Currently there are strict rules to regulate tourist visiting times and number of tourists per group, and limiting observation distance to 7m. A recent contribution by Klailova et al. [2010] argues that among other measures, a minimum observation distance $> 10$m might be desirable, as humans might alter the behaviour of gorillas.

[4] Habituation involves the loss of fear of humans before gorillas can be considered suitable

and military rebels in the forest (Plumptre and Williamson [2001]). Ultimately, the future sustainability and success of gorilla tourism hinges on the ability to attract high-end, low-impact tourist visitors.

## 3 The Bioeconomic Model

As noted above, there are several actors operating in the Virunga region: park agencies for each of the three countries, local communities in the vicinity of the national parks, and military rebels. In this section this paper builds a simple bioeconomic model to capture the interaction between broad groups of the different actors. To ensure tractability and allow us to only deal with poaching involving the local community, it considers only two key economic agents[5]: the Park Agency and a local community living adjacent to the park; and three possible land-uses: gorilla conservation/tourism, gorilla poaching and agricultural production. It assumes that land allocation has already been decided, such that each party must live with what they have.[6]

The Park Agency has the mandate to care for the gorillas, manage tourism and collect tourism revenues from gorilla tracking, mountain climbing and other related activities. It is assumed that there is no harvesting by the Park Agency even though there is poaching by the local community.

The local community engages in agricultural production, as well as poaching especially of infant gorillas for sale on the international market to private foreign zoos. The local community allocates its fixed endowment of labour effort ($\bar{N}$) between the two activities, namely agricultural production ($N_a$) and gorilla poaching ($N_g$). (See the appendix for a summary of definitions of symbols used). Therefore total labour effort is given as:

$$N_a + N_g = \bar{N} \tag{1}$$

Enforcement against poaching is done by the Park Agency, to whom fines levied on poachers accrue. Thus, gorilla poaching involves the risk or probability of being caught ($\theta$). The probability of detection is affected by the level of the

for visiting by tourists.

[5] As a reviewer pointed out there are other agents besides the local community who are involved in poaching. However, we only focus on poaching by the local community for two reasons. First, poaching by agents such as the militia require a policy response from national government rather than the parks agency e.g. deployment of the army. Second, poaching by external agents such as commercial gangs usually gets aided by locals who are more knowledgeable about the area. Once the incentives of the local collaborators have been removed then poaching by external agents will likely subside. In fact, Fischer et al. [2011] show that linking benefits of conversation to the actions of locals can result in significant conservation outcomes even after incorporating poaching by external agents.

[6] In reality, even though property rights are well defined, lack of enforcement results in encroachment; but that does not entail legally owning any additional land. Encroachment is a costless process. Since land is fixed, there is direct competition between the two agents. Encroachment of agricultural activities benefits the local communities but at the expense of the Park Agency, as it entails a significant reduction in gorilla habitat.

Park Agency's anti-poaching effort ($E$), and the local community's harvesting effort ($N_g$):

$$\theta = \theta(E, N_g) \tag{2}$$

We assume that $\theta(0, N_g) = 0$, $\partial\theta/\partial E > 0$ and $\partial\theta/\partial N_g > 0$, implying $\theta$ is an increasing function of the level of anti-poaching effort, and time spent on poaching gorillas, respectively. In addition, $\theta_{EN_g} > 0$, implying that as the level of anti-poaching effort increases, the probability of being detected increases at the margin.

While the intention of poachers is mainly to capture infant gorillas for sale to foreign zoos, in reality the capture of infants involves killing adult group members, as they normally protect the infants (Nellemann et al. [2010]).[7] Poaching therefore affects the entire gorilla population, motivating modelling the total gorilla stock rather than a sub-population. Assuming that the poacher's remuneration for each infant gorilla caught is $s$ and that the harvest/offtake function of gorillas is $h = h(G, E, N_g)$, the payoff function from gorilla poaching is given by:

$$\pi_g = s\kappa h - wN_g - \theta(\cdot)\Omega\kappa h = (s - \theta(\cdot)\Omega)\kappa h(G, E, N_g) - wN_g \tag{3}$$

where $N_g$ is the effort expended on poaching, $w$ is the cost per unit of effort, $\Omega$ is the fixed fine per unit poached when detected, and $\kappa$ is the fraction of infants in the gorilla offtake. It should be noted that the local community does not directly decide on the amount of gorilla offtake. Instead, it decides on the amount of labour to allocate to poaching, $N_g$ which alongside other variables determines the level of gorilla offtake. In addition, even though $h$ is the ultimate gorilla offtake by poachers, revenue is derived from infants ($\kappa h$) only.[8] It is assumed that $\partial h/\partial G > 0$ implying that a higher stock induces a higher illegal offtake, and $\partial h/\partial E < 0$ meaning that an increase in anti-poaching effort gives rise to reduced illegal offtake through increasing the probability of detection. Furthermore, $\partial^2 h/\partial E^2 \geq 0$: as anti-poaching effort increases, poaching will decline - at an increasing rate. Therefore the function $h$ is convex in $E$.

There is revenue sharing between the locals and the Park Agency with regard to the gross revenues from tourism. The locals are assumed to get a share $\alpha$ of the revenues from gorilla tourism, implying that the Park Agency gets the

[7] In most cases infants can only be captured after killing the adults (called silverbacks) in the group who are meant to protect them (UNEP .WCMC, 2003). In addition, there are social consequences often associated with the killing of a key member of a group, for example a silverback. This could cause the disintegration of an entire group; and infanticide, as nursing mothers join a new male, thereby triggering population regression (UNEP, Undated; Kalpers et al, 2003). Silverbacks often kill the infants after gaining control (following fights called 'interactions') of the group to establish dominance and to induce the females to start bearing infants again.

[8] Poaching effort has two effects: infant gorillas are captured and adult gorillas are killed while protecting their infants. Dead adult gorillas can be sold for bushmeat or trophy. However, there is a very small market for this in the Congo Basin (Nellemann et al. [2010]) hence we assume that dead adult gorillas have no value in our model to keep the analysis tractable. Of course, the implicit assumption is that poachers can only be effectively apprehended and fined if found in possession of evidence, i.e. infant gorillas (rather than just a gun even when they have killed an adult gorilla).

rest, $(1-\alpha)$, where $0 \leq \alpha \leq 1$. It is assumed further that these shares are fixed through a legal system.[9] Denoting the revenue from gorilla tourism at time $t$ by $R(G)$ implies that the amount of revenue going to the community is $\alpha R(G)$ with $0 \leq \alpha \leq 1$.[10]

It is assumed that the local community's agricultural production is affected by the labour used in agricultural production, $N_a$. Therefore the agricultural profit function is given by:

$$\pi_a = p_a Q(N_a) - wN_a \tag{4}$$

Where $w$ is the imputed wage rate (price of labour) which is assumed to be predetermined because of the general possibility of off-farm employment; $p_a$ is the fixed market price of agricultural output which is assumed to be exogenously determined for the local community since there exists a national market for agricultural output; $Q(N_a)$ is the total agricultural production function, and is assumed to be characterised by constant returns to scale. It is assumed that $Q'(N_a) \geq 0$, and $Q''(N_a) < 0$.

Thus the local community's net benefit from agricultural and wildlife actives is given by:

$$\pi_{LOC} = \pi_a + \pi_g + \alpha R(G) = p_a Q(N_a) - wN_a + (s - \theta(\cdot)\Omega)\kappa h(\cdot) - wN_g + \alpha R(G) \tag{5}$$

Equation (6) gives the Park Agency's net benefit from wildlife activities in the presence of a revenue sharing scheme with the local community.

$$\pi_{PAR} = (1-\alpha)R(G) + \theta(\cdot)\Omega\kappa h(\cdot) + Z(G) - c(G,E) \tag{6}$$

The total cost of managing the park and the gorillas in each time period is $c(G,E)$, which is assumed to depend on the gorilla stock as well as the anti-poaching effort. The Park Agency therefore faces costs associated with controlling and securing the benefits from the gorillas and their habitat by exerting anti-poaching effort (E). Such costs could be in the form of equipping and paying an anti-poaching unit. In return, the Park Agency receives three types of benefits: (i) share of revenue from gorilla tourism, $(1-\alpha)R(G)$,(ii) proceeds

[9] All the above assumptions are in line with reality: the local community in Rwanda currently gets about 5% of the net revenue; in Uganda 20% of park revenues go the same way (Stage et al. [2005]); and in the DRC, 30% of the cost of the gorilla tracking permit goes to the local community (Virunga National Park [2010]).

[10] Production activities such as actual tourist numbers are not explicitly modelled in the revenue function. Revenue is assumed to be related to the gorilla biomass, and $R(0) = 0$. In addition, $R'(G) > 0$and $R''(G) \leq 0$, implying that (all other factors remaining constant) a large biomass induces increased tourist visits but at a decreasing rate, as there will be more habituated gorillas to be visited. In reality, the number of visitors allowed depends on both the size of the gorilla group and the number of habituated groups. For example, in the Virunga National Park, six tourists are allowed to visit a gorilla family consisting of 10 or more individuals while only four tourists are permitted to visit a gorilla family with fewer than 10 individuals. While the total number of tourists visiting the gorilla families depends on the number of habituated gorilla families, at present a maximum of 30 tourists are permitted per day (Virunga National Park [2010]).

from poaching fines, $\theta(\cdot)\Omega\kappa h(\cdot)$, and (iii) the public good value of the gorilla stock, $Z(G)$. Endangered charismatic and rare species such as the gorilla often confer a public good value. It can take the form of existence value, bequest value or option value.[11] It is assumed that $Z(G) > 0$, $Z(0) = 0$, $Z'(G) > 0$ and $Z''(G) \leq 0$.

The production activities taking place inside the park (namely tourism and poaching of gorillas) are constrained by the gorilla stock dynamics. The change in the gorilla stock over time will be equal to the natural growth of the gorillas, less the illegal offtake.

$$\frac{dG}{dt} = F(G) - h(G, E, N_g) \tag{7}$$

Where$F(G)$captures the natural growth, which can take the form of a logistic growth function with depensation[12] and is represented by $F(G) = \eta G^{\phi}\left(1 - \frac{G}{K}\right)$, where $\eta$ is the intrinsic rate of growth of the gorilla stock and $K$ is the carrying capacity of the park, which is the gorilla habitat. It is also assumed that $F'(G) > 0$ and $F''(G) < 0$ in the domain $0 < G < K$. The natural growth of the gorilla $F(G)$ incorporates several factors, including the size of the habitat, the current structure of land use and gorilla mortality from disease and war.

# 4 Market Equilibrium

In the market equilibrium, both the local community and Park Agency legally benefit from revenue from gorilla tourism. However, the local community and the Park Agency pursue individual interests and consequently act uncooperatively. The local community is involved in poaching and ignores the public good value of the gorilla stock. The Park Agency takes the public good value of the gorilla stock into account and exerts anti-poaching enforcement to protect the gorilla. The local community makes decisions about labour allocation between its two livelihood activities while the Park Agency makes a decision about the level of anti-poaching enforcement. The local community takes the anti-poaching enforcement $E$ as given while the Park Agency takes the local community's poaching effort $N_g$as given until equilibrium poaching effort and anti-poaching enforcement values are attained.[13]

**The Local Community's Problem**

[11] On the one hand, where the public good is national, government incentives are necessary. On the other hand, where the public good is global, trade or international transfers are often needed.

[12] The parameter $\phi$ controls for depensation. If $\phi = 1$, there is no depensation. Depensation dynamics are therefore characterised by $\phi > 1$. The presence of depensatory dynamics affects the potential for recovery (Myers et al. [1995]).

[13] One form in which the interaction between the two agents might take is sequential. The local community first chooses poaching effort $N_g$, based on what it perceives as the likely response from the Park Agency. In the second stage, the Park Agency chooses enforcement effort $E$ after observing the poaching effort by the local community. Such iterations continue until equilibrium values are attained.

The decisions to be made by the local community relate to how much labour to allocate to gorilla poaching, $N_g$, and how much to allocate to agriculture, $N_a$. Given the existence of a labour constraint shown in equation (1), a decision on how much effort to allocate to one activity already implies a certain allocation to the other activity. Thus, the local community is confronted by the following maximisation problem, where the labour constraint has already been substituted:

$$\max_{N_g} \pi_{LOC} = p_a Q(\bar{N}-N_g)-w(\bar{N}-N_g)+[s-\theta(E,N_g)\Omega]\kappa h(G,E,N_g)-wN_g+\alpha R(G) \tag{8}$$

As shown in Skonhoft and Solstad [1998], the local community does not base its poaching decision on intertemporal considerations, since it does not have property rights over the gorilla and effective enforcement in subsequent periods might completely curtail its poaching. Uncertainty regarding the local community's ability to expropriate from the park in the future motivates it to disregard sustainable use of the gorilla.

The first-order condition with respect to poaching effort is:

$$p_a Q'(\bar{N}-N_g) = \underbrace{s\kappa\frac{\partial h(\cdot)}{\partial N_g} - \theta(\cdot)\Omega\kappa\frac{\partial h(\cdot)}{\partial N_g} - \Omega\kappa h(\cdot)\frac{\partial \theta(\cdot)}{\partial N_g}}_{\xi_1} \tag{9}$$

Thus, the local community will allocate labour to gorilla poaching according to the optimality condition given by equation (9). The marginal benefit of poaching effort consists of three components. The term $s\kappa\partial h(\cdot)/\partial N_g$ is the marginal (financial) value of poaching effort to the local community in terms of the value of the infants captured and sold. The term $-\theta(\cdot)\Omega\kappa\frac{\partial h(\cdot)}{\partial N_g}$ shows the marginal value (loss) to the local community in terms of the expected value of fines upon being apprehended and fined because of additional investment in poaching effort. The term $-\Omega\kappa h(\cdot)\frac{\partial\theta(\cdot)}{\partial N_g}$ shows the marginal value (loss) to the local community in terms of the value of fines upon being apprehended and fined when the risk of detection increases because of additional investment in poaching effort.

**The Park Agency's Problem**

The decision to be made by the Park Agency is how much anti-poaching enforcement $E$to invest in. As the Park Agency has a legal right to exploit the gorilla for tourism and its public good value, it has a long-term view, and therefore takes the dynamics of the gorilla stock into account. However, the Park Agency is likely to use a discount rate $\gamma$which is different from that used by the social planner. The Park Agency therefore faces the following problem, subject to the dynamics of the gorilla stock (7):[14]

$$\max_{E} \pi_{PAR} = \int_0^{\infty} [(1-\alpha)R(G) - c(G,E) + \theta(\cdot)\Omega\kappa h(\cdot) + Z(G)]e^{-\gamma t} dt \quad (10)$$

The following expression can be obtained from the first-order condition:

$$\frac{\partial c(\cdot)}{\partial E} = \Omega\kappa h(.)\frac{\partial \theta(.)}{\partial E} - \lambda\frac{\partial h(\cdot)}{\partial E} + \theta(.)\Omega\kappa\frac{\partial h(\cdot)}{\partial E} \quad (11)$$

The Park Agency will deploy anti-poaching effort up to the point where the marginal cost of the anti-poaching effort $\partial c(\cdot)/\partial E$ is equal to its marginal benefit. The marginal benefit of anti-poaching enforcement consists of three components. The term $\Omega\kappa h(\cdot)\partial\theta(\cdot)/\partial E$ shows the marginal (financial) value to the Park Agency in terms of the value of fines receivable upon apprehension of poachers when the risk of detection increases due to increased anti-poaching enforcement. The term $-\lambda\partial h(\cdot)/\partial E$ is the marginal (shadow) value to the Parks Agency of gorillas saved from poaching because of increased anti-poaching enforcement while the term $\theta(\cdot)\Omega\kappa\partial h(\cdot)/\partial E$ shows the marginal (financial) valuation by the Park Agency of fines forgone because of decreased offtake following additional investment in anti-poaching enforcement.

The co-state equation is given as$\dot{\lambda} - \gamma\lambda = -\partial H^{PAR}/\partial G$.

$$\frac{\dot{\lambda}}{\lambda} + \left[\frac{(1-\alpha)R'(G) - \partial c(\cdot)/\partial G + \theta(\cdot)\Omega\kappa\partial h(\cdot)/\partial G + Z'(G)}{\lambda}\right] + \eta\left(\phi G^{\phi-1} - \frac{(\phi+1)G^{\phi}}{K}\right) - \frac{\partial h(\cdot)}{\partial G} = r \quad (12)$$

The Park Agency would maintain the gorilla stock at a level that equates the return from the gorilla with the return from alternative assets. The marginal revenue from gorilla tourism is weighted by the share of such revenue accruing to the Park Agency. In steady state, $\dot{\lambda} = \dot{G} = 0$. Therefore, it can be shown from the co-state equation (12) and the equation for the dynamics of the gorilla stock that the optimal shadow value of the gorilla stock is:

$$\lambda^* = \frac{(1-\alpha)R'(G) - \partial c(\cdot)/\partial G + \theta(\cdot)\Omega\kappa\partial h(\cdot)/\partial G}{\frac{\partial h(\cdot)}{\partial G} - \eta\left(\phi G^{\phi-1} - \frac{(\phi+1)G^{\phi}}{K}\right) + \gamma} \quad (13)$$

The market equilibrium levels of poaching effort $N_g^*$, anti-poaching effort $E^*$and the stock of the gorilla $G^*$, can be computed from equations (7), (9) and (11). The steady-state offtake of the gorilla by the local community can be solved for by substituting these values into the harvesting function $h^* = h(G^*, E^*, N_g^*)$.

[14] In reality, Park Agencies may not really be expected to optimise (in the sense of maximising the present value of net benefits); they may only care about certain ecological outcomes, for example maintaining the stock of gorillas at a specific level. However, in reality they may also have to optimise (in the sense of maximising the present value of net benefits), given that they need resources for conservation, which is not adequately supported in Africa.

# 5 The Social Planner's Problem

The social planner chooses poaching effort and anti-poaching enforcement to maximise the present value of net benefits from agricultural and gorilla activities, including the public good value of the gorilla stock. Therefore, subject to the labour constraint (1) and the dynamics of the gorilla stock (7), the social planner is confronted with the following maximisation problem:[15]

$$\begin{aligned} \max_{E,N_g} PVNB &= \int_0^\infty [(1-\alpha)R(G) - c(G,E) + \theta(\cdot)\Omega\kappa h(\cdot) + p_a Q(N_a) - wN_a + \\ &\quad (s - \theta(\cdot)\Omega\kappa h(G,E,N_g) - wN_g + \alpha R(G) + Z(G)]e^{-rt}dt \qquad (14) \end{aligned}$$

The current-value Hamiltonian function is therefore given in equation (15) where the superscript denotes the social planner:

$$\begin{aligned} H^{sp} &= R(G) - c(G,E) + p_a Q(\bar{N} - N_g) - w(\bar{N} - N_g) + s\kappa h(\cdot) - wN_g + \\ &\quad Z(G) + \lambda[\eta G^\phi \left(1 - \frac{G}{K}\right) - h(\cdot)] \qquad (15) \end{aligned}$$

where $\lambda$ is the co-state variable, and the current value of the shadow price of a gorilla at any time $t$. The shadow price measures the approximate decrease in the present value of net benefits resulting from a unit decrease in the gorilla stock. The first order condition with respect to poaching effort is given by:

$$p_a Q'(\bar{N} - N_g) = \underbrace{s\kappa \frac{\partial h(\cdot)}{\partial N_g} - \lambda \frac{\partial h(\cdot)}{\partial N_g}}_{\zeta_0} \qquad (16)$$

The social planner will allocate labour between agriculture and gorilla poaching until the value of the marginal product of labour allocated to each activity is equalized. The marginal benefit of labour allocated to poaching consists of two components related to the valuations by the two agents for whom the social planner decides: the term $s\kappa\partial h(.)/\partial N_g$ shows the marginal (financial) value of poaching effort to the local community in terms of the value of the infants captured and sold while the term $-\lambda\partial h(.)/\partial N_g$ shows the marginal (shadow) loss of poaching effort to the Parks Agency in terms of its effect on the gorilla stock.

[15] It should be noted that by including revenues from poaching we are not judging it as a social good; in fact revenue from poaching is only considered good by certain groups of society not everyone. However, the role of the social planner is to balance the revenues (i.e. goods) and costs (i.e. bads) faced by different groups in society. Accordingly, as long as certain groups find revenue from poaching good (i.e. receive this revenue) then it will necessarily feature positively in the social planner's problem. The inclusion of the benefits of poaching in the social planner's problem is in line with existing literature and reflects the fact that these benefits accrue to a group that is part of the society (see for example Johannesen and Skonhoft, [2005]). Excluding revenue from poaching will underestimate the total benefits associated with gorillas and will underestimate the level of incentives required to reduce poaching.

The first order condition with respect to anti-poaching effort can be stated as:

$$\frac{\partial c(\cdot)}{\partial E} = -\lambda \frac{\partial h(\cdot)}{\partial E} + s\kappa \frac{\partial h(\cdot)}{\partial E} \tag{17}$$

Equation (11') states that the social planner should deploy anti-poaching effort up to the point where the marginal (financial) cost of the anti-poaching effort $\partial c(\cdot)/\partial E$ is equal to its marginal benefit. The marginal benefit consists of two components related to the valuations by the two agents for whom the social planner decides: the term $-\lambda \partial h(\cdot)/\partial E$ is the marginal (shadow) valuation by the Parks Agency of gorillas saved from poaching through marginal anti-poaching enforcement while the term $s\kappa\partial h(.)/\partial E$ is the marginal (financial) valuation by the local community of poaching income lost because of marginal anti-poaching enforcement.

The co-state equation is given as

$$\frac{\dot{\lambda}}{\lambda} + \left[\frac{R'(G) - \partial c(\cdot)/\partial G + s\kappa\partial h(\cdot)/\partial G + Z'(G)}{\lambda}\right] + \eta\left(\phi G^{\phi-1} - \frac{(\phi+1)G^{\phi}}{K}\right) - \frac{\partial h(\cdot)}{\partial G} = r \tag{18}$$

The social planner would therefore maintain the gorilla stock at a level that equates the return from gorillas with the return from alternative assets. The return from the gorilla stock is in terms of the change in the marginal valuation of the gorilla stock and stock effects on revenue from gorilla tourism, cost of anti-poaching enforcement, revenue from sale of infant gorilla by the local community, natural growth of the gorilla including offtake. In steady state, $\dot{\lambda} = \dot{G} = 0$. From the co-state equation (12') and the stock dynamics equation (7), it can be shown that the steady-state shadow value of the gorilla stock is

$$\lambda^{sp^*} = \frac{R'(G) - \partial c(\cdot)/\partial G + s\kappa\partial h(\cdot)/\partial G + Z'(G)}{\frac{\partial h(\cdot)}{\partial G} - \eta\left(\phi G^{\phi-1} - \frac{(\phi+1)G^{\phi}}{K}\right) + r} \tag{19}$$

The steady state equilibrium levels of poaching effort $N_g^{sp^*}$, anti-poaching effort $E^{sp^*}$ and the stock of the gorilla $G^{sp^*}$, can be computed from equations (7), (9') and (11'). Subsequently, one can solve for the steady state offtake of the gorilla by the local community by substituting these values into the harvesting function $h^{sp^*} = h(G^{sp^*}, E^{sp^*}, N_g^{sp^*})$.

**Comparison with the Market Equilibrium**

The market equilibrium and social optimal levels of poaching effort, anti-poaching effort and the stock of the gorilla can be assessed by comparing equations (9) and (11) to (9') and (11') respectively. From equations (9) and (9'), where $\zeta_1 < \zeta_0$, the value of marginal product of labour allocated to agriculture is lower and the return from poaching effort is higher in the market equilibrium than in the social planner's solution[16]. Consequently, the value of $N_g$ will

[16] That is, $\left[\begin{array}{c} \zeta_1 = \left(s\kappa\frac{\partial h(\cdot)}{\partial N_g} - \theta(\cdot)\Omega\kappa\frac{\partial h(\cdot)}{\partial N_g} - \Omega\kappa h(\cdot)\frac{\partial\theta(\cdot)}{\partial N_g}\right) < \\ \left(s\kappa\frac{\partial h(\cdot)}{\partial N_g} - \lambda\frac{\partial h(\cdot)}{\partial N_g}\right) = \zeta_0 \end{array}\right]$

be higher in the market equilibrium and lower in the social planner's solution. One of the policies which could be used to redistribute effort from poaching to agriculture is to make the agricultural activity more valuable. However, this is only true where the human population does not exceed the carrying capacity of the available agricultural land. If the population is already excessive for the agricultural land available then more valuable agricultural activity would lead to the opening up of parklands for agriculture. In fact, Schulz and Skonhoft [1996] show that policies to conserve wildlife by increasing agricultural productivity in areas neighbouring protected areas might be inappropriate because increasing agricultural product prices in an area with massive population pressure will lead to a lower wildlife stock size in the long run. The area in question is thought to be under severe population pressure which is one of the reasons why the local community tolerates poaching so as to free up more land for their agricultural activities rather than gorilla conservation. Thus, we should focus on policies such as benefit sharing schemes which do not necessarily increase the scale of agriculture. Comparing the optimality conditions (11) and (11') for anti-poaching enforcement reveals that $E^* > E^{sp^*}$ i.e. anti-poaching enforcement will be higher in the market equilibrium and lower in the social planner's solution.

From the above comparisons, it is therefore clear that the gorilla stock is larger for the social planner i.e. $G^{sp^*} > G^*$. Comparing equations (13) and (13'), it may be noted that the optimal shadow value of the gorilla stock is higher in the social planner's scenario. This is because the marginal returns in the social planner's solution are higher than in the market equilibrium i.e. $[R'(G) - \partial c(\cdot)/\partial G + s\kappa\partial h(\cdot)/\partial G + Z'(G)] > (1-\alpha)R'(G) - \partial c(\cdot)/\partial G + \theta(\cdot)\Omega\kappa\partial h(\cdot)/\partial G + Z'(G)$, since the social planner also takes into account the marginal valuations of the gorilla stock by the local community (i.e. the local community's marginal revenue from poaching and the local community's share of marginal revenue from gorilla tourism).

**Analysis of the Current Breed of Benefit Sharing Schemes**

From the above analysis we can conclude that the market equilibrium gorilla stock in central Africa is suboptimal even in the presence of the current revenue sharing scheme. In fact, the gorilla stock will not reach its socially optimal level in the market equilibrium, with or without a revenue sharing scheme. In the case where i.e. there is no revenue sharing scheme - implying that all tourism-related income accrues to the Park Agency - equations (9) and (11) reveal that the market equilibrium amounts of poaching effort and anti-poaching enforcement would not be materially different from those in the presence of revenue sharing. Thus, the revenue sharing scheme has no effect on conservation outcomes because it is not internalised by the local community. However, revenue sharing obviously has an effect on community welfare in as far as it provides additional incomes. In central Africa, the local community's share of proceeds from gorilla tourism is invested in social infrastructure such as schools and water tanks (Nielsen and Spenceley [2010]).

In order to align market equilibrium with the social planner's solution, a different intervention will be needed. On the side of the local community, a market equilibrium outcome similar to the social planner's solution can be achieved by setting the fine in such a way that equations (9) and (9') are equalized. Starting with equalized marginal benefits of poaching effort, $\lambda \partial h(\cdot) N_g = \theta(\cdot)\Omega\kappa\partial h(\cdot)/\partial N_g + \theta(\cdot)\Omega\kappa\partial h(\cdot)/\partial N_g$. Further manipulation and rearrangement yields the following expression:

$$\Omega^* = \lambda/\kappa\,[\theta(\cdot) + h(\cdot)\partial\theta(\cdot)/\partial(\cdot)] \tag{20}$$

The expression for $\Omega^*$ has the interpretation of an optimal fine, which if imposed on the local community for poaching potentially ensures a market equilibrium outcome similar to the social planners' solution. Therefore, instead of setting the fine arbitrarily, the poaching fine has to cover the full cost of poaching actions, which disincentivises poaching. However, obtaining the necessary information about some of the arguments required to compute the optimal fine is a challenge.[17] Furthermore, an optimal fine does not incentivize the local community to take a long-term view of its interaction with the gorilla stock. As a result, an optimal fine alone will not bring convergence between the market equilibrium and the social planner's solution. The devolution of wildlife property rights has been suggested as a solution in literature (see Skonhoft and Solstad [1998] and Songorwa [1999], for example). However, the mere designation of the local community as co-owners of wildlife has not brought sustained conservation practices for some communities (for example, CAMPFIRE communities in Zimbabwe as studied by Fischer et al. [2011]). Such participatory schemes rely heavily on active community involvement in areas such as problem identification, planning, implementation, monitoring and evaluation (Songorwa [1999]) and the community expects an adequate payoff for their continued engagement. In order for devolution of property rights to positively affect conservation practices, it needs to simultaneously bring tangible benefits to the local communities.

**Performance-linked Benefit Sharing Scheme**

In this section we propose a performance-linked benefit sharing scheme in which the Park Agency pays the local community a payment directly linked to the growth in the gorilla stock. Zabel et al. [2011] have also suggested a similar scheme for tiger conservation in India where predation incidents greatly impact households' income and retaliatory killing threatens endangered carnivore species' survival. This alternative benefit sharing scheme has two advantages over the current revenue sharing scheme: the local community's welfare is enhanced as it earns more from the gorilla and the local community is incentivized

[17] While reforming the current revenue sharing scheme by moving towards the optimal fine might move the gorilla conservation towards social optimality, the policy imposes a huge regulatory burden on the Park Agency due to its enormous information requirements. Regulators often do not possess the superior information possessed by poachers who however have no incentive to share it with the regulators. Not only does the Park Agency have to decide how huge the optimal fine ($\Omega^*$) should be, the Agency also has to define the optimal enforcement effort (here the Agency would have to grapple with evaluating the effect of an increase in enforcement officers against initiatives such as giving them additional hi-tech enforcement equipment or upgrading their skills levels). This is further compounded by the fact that the Park Agency interacts with the local community in a dynamic set up and hence an optimal policy could be rendered suboptimal in the next period of interaction.

to take a long-term view of its interaction with the gorilla stock as payments are based on the dynamics of its stock.

To assess its impacts, the proposed alternative benefit sharing scheme can now be incorporated into the local community and Park Agency's maximisation problems, where the payment for the growth in the gorilla stock ($\dot{G}$ as defined in equation 7) is denoted by $\Psi$. The local community is now confronted by the following maximisation problem, subject to the labour constraint (1):

$$\max_{N_g} \pi_{LOC} = p_a Q(N_a) - wN_a + [s - \theta(E, N_g)\Omega]\kappa h(\cdot) - wN_g + \Psi\dot{G} \tag{21}$$

The first order condition with respect to poaching effort is given as:

$$p_a Q'(\bar{N} - N_g) = \underbrace{s\kappa\frac{\partial h(\cdot)}{\partial N_g} - \theta(\cdot)\Omega\kappa\frac{\partial h(\cdot)}{\partial N_g} - \Omega\kappa h(\cdot)\frac{\partial\theta(\cdot)}{\partial N_g}}_{\zeta_1} - \Psi\frac{\partial h(\cdot)}{\partial N_g} \tag{22}$$

Here, the marginal benefit from poaching effort differs from its counterpart in the social planner's solution.[18] However, the comparison between equations (18) and (9') shows that setting $\Omega = 0$ and $\Psi = \lambda$ would align the current expression for the marginal benefit from poaching effort with its counterpart in the social planner's solution. The aligned expression from the local community's problem would consist of two terms showing marginal valuations by the same agent (unlike two agents in the social planner's solution): the term $s\kappa\partial h(\cdot)/\partial N_g$ shows the marginal (financial) value of poaching effort to the local community in terms of the value of the infants captured and sold while the term $-\lambda\partial h(\cdot)/\partial N_g$ shows the marginal (financial) loss to the local community due to poaching effort displacing payments receivable had there been no additional offtake which could have added to the gorilla stock. Consequently, the local community will desist from poaching as it can earn more from an intact gorilla stock than from poached gorilla i.e. $\lambda > s\kappa$ and therefore $\Psi > s\kappa$. It should be noted that in some ways it seems that the proposed benefit sharing scheme could be quantitatively similar to a high fine policy. However, the truth is that the fine policy is reactive and only affects the local community with a probability of $\theta$ while the proposed benefit-sharing scheme is proactive and always affects the local community as long as there is stock growth.

The Park Agency maximizes the following problem, subject to the dynamics of the gorilla stock in equation (7):

$$\max \pi_{PAR} = \int_0^\infty \left[R(G) - c(G, E) + \theta(\cdot)\Omega\kappa h(\cdot) - \Psi(\dot{G}) + Z(\dot{G})\right] e^{-\gamma t} dt \tag{23}$$

The first order condition can be expressed as:

$$\frac{\partial c(\cdot)}{\partial E} = \Omega\kappa h(.)\frac{\partial\theta(.)}{\partial E} - \lambda\frac{\partial h(\cdot)}{\partial E} + \theta(.)\Omega\kappa\frac{\partial h(\cdot)}{\partial E} + \Psi\frac{\partial h(\cdot)}{\partial E} \tag{24}$$

[18] The marginal benefit from poaching effort is also lower than the market equilibrium one shown in equation (10') by the term $\Psi\partial h(\cdot)/\partial N_g$.

Given that $\Omega = 0$ and $\Psi = \lambda$ for a socially optimal outcome on the local community's side, we would therefore have $\partial c(\cdot)/\partial E = 0$ on the Park Agency's side. Such a result implies that the Park Agency would choose zero anti-poaching enforcement. This is a plausible result in that once the local community is adequately incentivized through payment linked to the growth in the gorilla stock it will stop poaching and, therefore, the Park Agency does not need to invest in any anti-poaching enforcement. Thus, under the performance-linked benefit sharing scheme we have $E^{pps^*} = 0$. Given that the new equilibrium levels of poaching effort $N_g^*$ and anti-poaching effort $E^*$ are zero, the steady-state offtake of the gorilla by the local community also becomes zero i.e. $h^* = h(G^*, E^* = 0, N_g^* = 0) = 0$. The stock of the gorilla $G^*$ rises to a level consistent with social optimality with no offtake.

To summarize, the proposed benefit sharing scheme involves the Park Agency paying the local community an amount of money directly linked to the growth in the gorilla stock. This scheme would simultaneously set the fine for poaching the gorilla to zero while setting the payment to the local community at , which is equal to the shadow price of gorillas. The performance-linked benefit sharing scheme would guarantee the growth in the gorilla stock to a level consistent with social optimality with no offtake. Since the incentives going to the local community are linked to the gorilla stock, an increase in the stock of the gorilla directly translates into an increase in income going to the local community and therefore enhanced community welfare.

**The Potential for Extracting Surplus Rents**

While the above scheme guarantees social optimality, the implementation of such a scheme requires significant financial resources. The payment of $\Psi$ (which should equal the shadow value of the gorilla) to the local community implies that the local community receives an amount made up of both the financial and the non-financial benefits associated with the gorilla since the shadow value also embodies non-use values of the gorilla e.g. existence, bequest and option values. This poses challenges to the viability of the scheme since the gorilla tourism revenue accruing to the Park Agency is only with respect to the use value of the gorilla.

As a starting point, additional financial resources could be generated by reforming the pricing of gorilla tracking (tourism) permits. Because of ecological considerations, visitors are currently limited to about 8 people per group per day (Moyini and Uwimbabazi [2000], Fawcett et al. [2004], ORTPN/IGCP and Homesy [1999] cited in Nielsen and Spenceley [2010]). What are the implications of having a small population of the gorilla such that visitation must be rationed? Since the mountain gorilla is only found in central Africa (i.e. the Virunga Massif and Bwindi Impenetrable National Park), the interdependence between the three Park Agencies controlling these areas has oligopolistic features. The provision of gorilla tourism is therefore characterised by natural barriers to entry, implying that the risk of losing customers to potential entrants or competitors is non-existent. Therefore the Park Agencies could generate higher revenues by charging prices consistent with their oligopoly nature.

In addition, the international community must have an interest to support conservation financially beyond tourism visits since the price for gorilla tracking permits only equates to the private benefit and not the public benefit associated with the gorilla. External financial support for benefit sharing schemes around gorilla conservation could therefore be the financial expression of $Z(G)$. One practical way for raising external financial support might be to impose a gorilla conservation levy on all international visitors at the ports of entry into the gorilla states. The resultant revenues would then be earmarked for the gorilla benefit sharing scheme. This could therefore help address the potential financial shortfall associated with a performance-linked benefit sharing scheme.

**Discussion**

Local communities will engage in poaching as long as the return from such activities exceeds the returns from alternative activities. This is partly fuelled by the high incidence of poverty in these areas. Therefore, in order to persuade communities living in the vicinity of the gorilla habitat to be partners in gorilla conservation, a stable flow of financial resources linked to their cooperation in gorilla conservation is required. It is important that disbursements are linked to the attainment of specific conservation goals (Ferraro and Simpson [2002], Zabel et al. [2011]) e.g. the growth in the stock of the gorilla.

The proposed performance-linked benefit sharing scheme also only requires the Park Agency to do a regular census and thereafter make payments accordingly thereby reducing burden on the regulator and encouraging self-monitoring by the local community. Conducting gorilla censuses is already the mandate of the Park Agency. In addition, the Park Agency does not need to know anything about the local poaching community's behavior since the proposed scheme is incentive compatible with an inbuilt driver of permanency of good behavior by the local community. Moreover, locals face an implicit fine should they decide to poach as their hidden actions are revealed in the next gorilla census and thus penalised accordingly. With a performance-linked benefit sharing scheme, the local community is effectively locked into a binding contract with the Park Agency and therefore assumes full responsibility for the stock dynamics. Since any action that enhances the gorilla stock directly translates into increased transfers to the local community, the local community might become proactive in resource conservation.

If the importance of tourism in supporting gorilla conservation and the current benefit scheme is recognised, then there is a need to consolidate the current tourism gains through the 'harmonisation' of rules and regulations, as this would reduce costly competition and strengthen collaboration. Since the benefit sharing scheme is mainly about sharing tourism gains, integrating activities would reduce costs and ultimately increase the amount available for gorilla conservation. It would allow the exploitation of country-specific attractions such as active and inactive volcanoes, lakes, bird viewing, and the fascination of different cultures, which could all enrich the tourism experience and boost revenue. At the same time this calls for the implementation of an optimal pricing strategy. The attractiveness of a regional transboundary initiative lies in its possible ability to insulate the economic activities in the area from political instability. Though not addressed directly by this study, this is an area ripe for further investigation.

Another important consideration not directly deriving from this model is the need for the benefit sharing scheme to incorporate the heterogeneity of the Virunga Massif in terms of tourism revenue generation capacity. Some sectors are likely to generate less revenue because of infrastructure differences and political instability, in addition to having fewer habituated gorillas. In such instances, Muchapondwa and Ngwaru [2010] argue that benefit sharing will help to solve transboundary environmental conservation problems if there is substantial cross-subsidisation in the short to medium term. It follows that the equalisation of benefits across the three countries would assume prominence, since unequal benefit sharing schemes might give rise to unequal cooperation.[19] This is important, given the current variation in the proportions going to local communities in the three countries. Therefore, the focus should be on effectively managing the entire Virunga Massif, rather than portions thereof, in order to consolidate the current gains in gorilla conservation.

# 6 Conclusion

Conserving the endangered gorilla in Rwanda, Uganda and the Democratic Republic of Congo which is characterised by slow population growth and facing a multitude of threats is a daunting task. This paper sets out to investigate the possible resolution of the poaching problem using benefit sharing schemes with local communities. Using a bioeconomic model, the paper demonstrates that the current revenue sharing scheme with the local communities yields suboptimal conservation outcomes. To this end, the paper also considers an alternative benefit sharing scheme which involves the Park Agency paying the local community an amount of money directly linked to the growth in the gorilla stock. It is shown that a performance-linked benefit sharing scheme can achieve socially optimal conservation. Through linking payments to the stock growth, the local community explicitly takes into account the gorilla stock dynamics. The scheme renders poaching effort by the local community, poaching fines on the local community and anti-poaching enforcement against the local community unnecessary. The oligopolistic interdependence between the only three countries offering gorilla tourism offers the prospect of extracting surplus rents which could be channelled towards more gorilla conservation. Given the huge financial outlay requirements for the ideal benefit sharing scheme, the Park Agencies in central Africa could reap more financial benefits for use in conservation if they employ an oligopolistic pricing strategy for gorilla tourism. The dynamic nature and severity of the threats to the gorillas mean that there is a need for ongoing, active involvement of all stakeholders. Equal benefit sharing among the three countries could significantly enhance the effectiveness of the benefit sharing scheme. It is therefore important to manage the area as a single park

[19] Due to the high irreplaceability associated with the area, investing in sensitising the main actors in the Virunga Massif (i.e. local communities, the Park Agency and military rebels) is crucial for gathering support for the benefit sharing scheme.

with a common objective.

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## APPENDIX A

**Figure 1:** The distribution of the mountain gorilla (Gorilla beringei beringei)


Source: International Gorilla Conservation Programme (IGCP)

Figure 1 shows the Virunga Conservation Area, which contains the Virunga National Park (Parc National des Virunga) in the Democratic Republic of Congo (DRC), the Mgahinga Gorilla National Park in Uganda, the Volcanoes National Park (Parc National des Volcans) in Rwanda and the Bwindi Impenetrable National Park (BINP) in south-west Uganda, on the border with the DRC.

## APPENDIX B

**Table 1:** Notation Used

| | | | |
|---|---|---|---|
| $G$ | Gorilla stock | $h$ | Harvesting function of gorillas |
| $F(G)$ | Gorilla natural growth dynamics | $s$ | Poacher's remuneration for each gorilla caught |
| $p_a$ | Price of agricultural products | $w$ | Cost per unit of effort of labour |
| $Q(N_a)$ | Total agricultural production function | $R(G)$ | Revenue from gorilla tourism |
| $N_a$ | Labour effort devoted to agricultural production | $\pi$ | Profit function |
| $N_g$ | Labour effort devoted to gorilla poaching | $\alpha$ | Fixed share of revenue going to locals |
| $\theta$ | Probability of being caught poaching gorillas | $\beta$ | Fixed share of profits accruing to locals |
| $E$ | Park Agency's antipoaching effort | $c(G,E)$ | Total cost of managing the park |
| $\Omega$ | Fixed fine per unit poached if caught | $K$ | Park land carrying capacity |
| $Z(G)$ | Public good externality | $r$ | Social Planner's discount rate |
| $\kappa$ | Fraction of infants in the removed population | $\psi$ | Payment for the growth of the gorilla stock |